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TECHNIQUES AND APPARATUS FOR THE SCIENCE TEACHER

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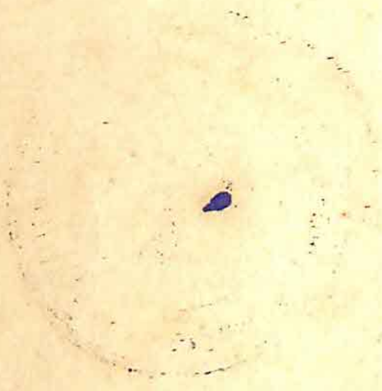

TECHNIQUES AND APPARATUS
FOR THE SCIENCE TEACHER

A. G. Beleson and H. Creaser

TECHNIQUES AND APPARATUS

FOR THE

SCIENCE TEACHER

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INTRODUCTION

This book has grown out of a series of courses designed to improve science teaching in East Africa. Its purpose is to help the science teacher to become familiar with hand tools, simple techniques and materials with which inexpensive science apparatus can be made for use in the classroom. It is designed to develop confidence on the part of the teacher in his ability to construct apparatus himself.

Many scientists regard their early training in the manual skills as their greatest asset and one of the most important parts of their education. The science teacher who has a knowledge of how to use tools and materials can give originality to his teaching, and he can keep his equipment in good working order at all times.

Once a teacher has mastered the basic techniques, and seen how easy it is to create and construct apparatus, he can present opportunities for his pupils to construct their own apparatus.

The energy of a pupil can be channelled into an exciting science programme by a confident and enthusiastic teacher who is familiar with modern methods and equipment. Pupils must *do* things if they are to learn. They must be able to answer the 'why' and 'how's' that come to their minds when they observe various science activities. There are two ways for pupils to gain information, through first-hand experience and through other people's experiences. First-hand experiences are generally vivid and well-remembered. In a science course where the apparatus is constructed by the pupil, it is possible to put the emphasis on first-hand experience. A pupil who is able to construct his own apparatus can carry on his science education outside as well as inside the classroom.

The first part of this book outlines the techniques of simple wood-work and metal-work, of soldering and glass-working. These techniques are basic to the science teacher and we have tried to present them in as simple a way as possible.

In the second part of the book we have detailed a number of pieces of apparatus that can be constructed very easily. The emphasis is always on simplicity, but all the pieces have been thoroughly tested and are effective.

Because of the simplicity of the apparatus, the scientific prin-

ciples that a teacher is trying to emphasize are more easily understood completely than is the case when apparatus is complex.

If we encourage teachers and teachers-in-training to produce some apparatus themselves where they have not done so before, then this book will have served the purpose for which it is intended.

CONTENTS

For Robert and Richard Beleson

1 ORGANIZATION AND SAFETY IN THE LABORATORY AND WORKSHOP

Safety Rules

This information is a reminder to the teacher that the right way to do a job is the safe way. It is impossible to list all the safety rules, but here are some rules or suggestions that should guide you in your laboratory or classroom when you are dealing with tools, machines, chemicals, general science apparatus, glass tubing and other glass-ware, high voltage electricity, etc. It is the teacher's job to make each student safety conscious. It is also the teacher's job to be safety conscious himself in his workshop and laboratory.

The list of rules below is not in order of importance, nor is it intended as a list to be pinned up in a laboratory. It is simply a reminder to the teacher, so that he can in turn remind his class.

1. Deposit all oily rags into a metal container.
2. Never bring any unknown liquids near an open flame.
3. Never clean off a work-bench or laboratory table with your bare hand; always use a brush or a wooden scraper.
4. Remove rings, wrist-watches, pendants and other ornaments while working with tools and machines. Keep your tie and hair tucked out of the way.
5. Place all scraps of wood, metal and glass into the rubbish bin immediately.
6. Store kerosene, petrol, benzene and all other inflammable liquids in approved fireproof containers. A fire extinguisher or a bucket of sand should be available. A first-aid kit should also be available.
7. Always wear goggles or an eye-shield when using a grinder. It is necessary to take every precaution to protect your eyes.
8. Do not over-estimate your ability to lift heavy or bulky objects, but ask for help.
9. When gas stoves and bunsen burners are to be used, instruct the students as to the proper method of lighting them. It is best to use a friction lighter. Be sure to instruct the students as to the proper method of disposing of the used matches.
10. Stoves of any kind, whether gas or electric, should not be

placed on a bench or a laboratory table unless the table is protected by asbestos, stone or asbestos-insulated metal.

11. Check all gas-hose connections regularly for leaks. It is best to clamp connections with a special hose-clamp.
12. All glass-working should be done on an asbestos pad. Glass retains heat for a long time; it is very deceptive. Hot glass can cause very severe burns.
13. Never pick up a soldering-iron except by the handle. Never assume that the iron is cool. Always rest the iron, hot or cold, on an asbestos or stone surface.
14. Do all soldering on an insulated bench or table.
15. Do not plug in any device or project that you have made until you have checked the circuit thoroughly.
16. Do not generate any gas in an unventilated room.
17. When inserting glass tubing in rubber stoppers, use fire-polished glass tubing. Lubricate the tube and the rubber stopper with soap and water or petroleum jelly, grasp the tubing close to the end entering the stopper and force the tube into the hole using a rotary motion. Protect your hand with a glove or a rag to avoid cuts should the tube break.
18. Handle all corrosive substances with great care. Never add water to concentrated sulphuric acid. *Always add the acid to the water.*
19. Store containers of dangerous chemicals like acids and alkalis on the floor or on a low shelf. Be sure to label all bottles. Discard the contents of unlabelled bottles.
20. Do not pour acids down the drain unless the plumbing is resistant to corrosive chemicals (check and find out). Laboratory sinks are usually constructed to handle acids.
21. Keep chemicals out of reach of irresponsible persons. If possible keep the chemicals locked up.
22. Try to anticipate the results of your experiments. Analyse the experiment for safety factors. This will prevent injuries.
23. Caution students not to experiment at home with dangerous chemicals. This may save a lot of eyes and fingers from injury.

NOTE: Many safety posters are available from insurance companies or industrial plants. Industry also offers many posters of educational value that can be used by the teacher for display in classrooms and laboratories.

Every laboratory or workshop should have an Organization Plan so that each pupil has an opportunity to share some responsibility in its running. The table below is an example of such a plan.

Organization Plan

FORM	ORGANIZATION	DATE
JOB	First Half-Term	Second Half-Term
PREFECT IN CHARGE	John	James
TOOLS (out)	Peter	
TOOLS (in)	etc.	
SAFETY	etc.	
SUPPLIES (out)		
SUPPLIES (in)		
BLACKBOARD		
WINDOWS and DOORS		

The jobs can be changed half-termly, as shown in the specimen plan, or even monthly or weekly as the teacher thinks most convenient.

Jobs in a Workshop

Tools The student looking after *tools* must check them at the beginning and end of the work period. He should report all missing or damaged tools to the teacher.

Supplies The student must examine the supplies, discard old sandpaper, straighten out the sandpaper blocks, straighten out the containers of nails and screws, etc. He must pick-up all stray nails and screws and put them in their proper boxes or containers according to size and gauge.

Blackboard The student must see that the blackboard is cleaned properly and ready for use. Before erasing anything from the board, he must check with the teacher that it is not needed for another class.

Safety The student must check the room for all hazards such as open gas jets, leaking connections on bunsen burners, or electric soldering-irons that have not been disconnected at the end of the period. He must also check the floor for scraps of wood or

metal or anything else that might cause a person to slip and fall down.

Every laboratory or workshop should have a *prefect* in charge of all the above activities. He should check to see that everyone does his job. He should also tell the class when to stop work and clean up properly if the teacher is busy or elsewhere. All students must assist in returning the tools, and in the general clean-up of the laboratory or workshop. The *organization* should be tailored to fit the type of activity that is taking place in the particular room. In the case of a laboratory, *apparatus* replaces *tools* in the above plan; *chemicals* might replace supplies; etc.

It is important in all plans that the pupils know exactly what their job involves. An organization plan should be designed to ensure that pupils co-operate fully with the teacher and with each other in the proper running of the laboratory or workshop. It should teach them responsibility and, most important of all, it should make them see that 'Science' is not simply walking into a laboratory and finding everything ready, or walking out and leaving somebody else to clear up.

Some teachers may like to 'mark' the pupils in the job they are doing. There is no need to lay emphasis on this in front of the pupils, but the 'marks' can serve as a guide when assessing pupils at the end of term, etc.

2 CLASSIFICATION, USE AND STORAGE OF TOOLS

Classification

We classify tools according to their use: whether for metal-work or for wood-work. Common sense must be the guiding factor. Certain tools may be used both for metal-work and wood-work, while others are specific to one or the other because of the design of the tool concerned and the type of steel used in its making. A scriber works very nicely when marking lines on metal surfaces; however, when used on wood it tends to follow the grain or to tear the grain of the wood.

As a general rule, if the tool is designed to cut metals it is made out of tool-steel that has been tempered to withstand the shock and the heat to which the tool will be subject in its everyday use. Files are really metal-working tools, but there is no reason why one should not use a file to shape a piece of wood. A rasp is the only true wood-working file, and it should not be used on metal because of the design of the teeth on the rasp. Similarly, a wood chisel having a cutting bevel of 30° is not suitable for metal-work, whereas a cold chisel with a point angle of at least 60° is suitable.

Good tools are made of *tool-steel*, a refined steel with a carbon content from 0·7 per cent. to 1·5 per cent. and able to withstand the heat treatment (hardening and tempering) that gives the tool the necessary characteristics needed for its particular work. In cases where the tool must withstand a very high degree of temperature, but must still maintain a good cutting-edge, tungsten is alloyed to the steel. A good example of such a case is a high quality hacksaw blade.

Cutting tools

WOOD Knife: sloyd, draw
Chisel: tang, firmer, mortise
Planes: block, smooth, jack, router, jointer, etc.
Saws: coping, back, rip, cross-cut, keyhole, compass, dovetail, etc.
Spokeshave
Scraper
Gouges: plain, carving

METAL Saw: hack
Cold Chisel: flat, cape round-nose, diamond
Tin-Snips: straight, curved, duck-bill, aviation snips—bench shears
Nippers: end-cutting, side-cutting, diagonal-cutting
Reamers: tapered, straight

Pounding tools

WOOD Hammer: claw (nails), tack
Mallet: wood, plastic, rawhide

METAL Hammer: ball-peen, riveting, setting, cross-peen, machinist hammer, art-metal hammers, sledge

Boring and drilling tools

WOOD Auger:
Bits: twist-bits, gimlet-bits, expansive-bits, forstner-bits, reamer-bits, countersink-bits, dowelling-jig, plug-cutter bit, hole-saw, fly-cutter, etc.
Bit brace, hand drill

METAL Twist-drills, countersink-reamers (straight and tapered) centre-drill, hole-saw, fly-cutter;
hand drill, electric drill, drill press

Metal forming tools

bench-stakes, forming-rolls, bar-folder, seaming-pliers, pan-brake, art-metal hammers, etc.

Abrading tools

scrapers, files, rasps, wire-brush, file card, steel-wool, glass-paper (sandpaper), emery-cloth, pumice-stone, scrapers, etc.

Punching tools

solid or pin punches, hollow punches, chasis-punches, centre punches, nail-punch (nail set), rivet set, hand-groover

Holding tools

Pliers: vice-grips, wire-cutting pliers, gas-pliers, round-nose pliers, flat-jaw pliers, combination pliers, etc.: tongs

Clamps: 'G' clamps, bar-clamp, spring-clamp, hand-screws, engineer's-vice (machinist-vice), woodworking-vice

Layout and testing tools

WOOD pencil, compass, dividers, marking gauge, try-square, combination-square, framing-square, steel rule, scale, trammel-points, 'T' bevel, protractor, etc.

METAL scriber or scratch awl, combination-square, calipers, dividers, steel scale, centre gauge, surface and depth gauge, vernier, hermaphrodite calipers, micrometer

Miscellaneous tools

putty knife, saw-set, furnisher, taps, dies, soldering-irons (plain and electric), screwdrivers (plain, Philips', offset, ratchet, etc.), wrenches (Allen, box, Stillson, monkey, open end, etc.)

Note: The above list is not all-inclusive: it simply includes tools usually found in a well-equipped workshop.

What should be bought first?

It is impossible to buy all the tools listed at once. Below is a suggested list of tools in the order that they might be purchased. The tools that any teacher has are personal to him, and many people will disagree with the tools suggested. The authors have found that the tools at the head of the list are most useful for the teacher starting off a small workshop, and when he has these he can add the tools he then feels most in need of.

It need hardly be said that good quality tools are the cheapest in the long run.

A Basic Tools

hammer
12-inch tenon-saw
screwdriver (8 inches to 9 inches long with a blade $\frac{1}{4}$ inch wide)
pair of pliers (6 inches)
pair of shears (tinsmith, 8 inches)
soldering-iron (medium size)
solder and flux
bradawl
trimming-knife (with spare blades)
small, steel (bow) metal-saw (and spare blades)

The above set of tools will enable a teacher to make and repair

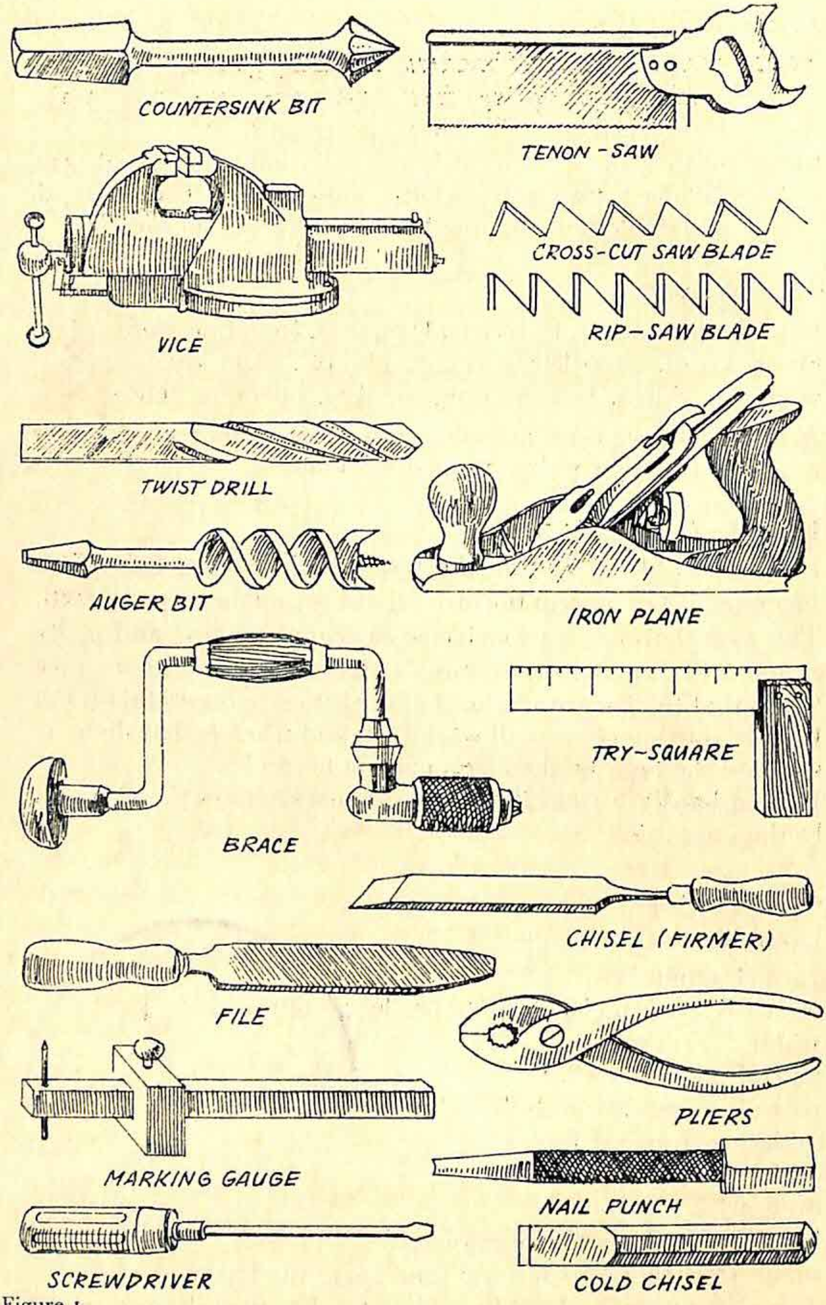

COUNTERSINK BIT
TENON-SAW
CROSS-CUT SAW BLADE
RIP-SAW BLADE
VICE
TWIST DRILL
AUGER BIT
IRON PLANE
BRACE
TRY-SQUARE
CHISEL (FIRMER)
FILE
PLIERS
MARKING GAUGE
NAIL PUNCH
SCREWDRIVER
COLD CHISEL

Figure 1

a great deal of apparatus. The apparatus made may look rough, but it will be adequate.
The *trimming-knife* to some extent replaces chisels and planes, the *bradawl* is used to make holes in wood before fixing screws. The *small, steel bow-saw* costs only a shilling or two and replaces the larger hacksaw: for many small jobs it is much better. The *tenon-saw* becomes an all-purpose saw, doing many jobs for which it was not wholly designed.
Many people feel the need for a small plane and chisels even at an early stage. Others want a carpenter's brace and a set of centre-bits and auger bits, which are commonly used with a bit brace. Still others prefer to have a hand drill and set of twist-drills. As we said earlier, once a basic set of tools is obtained, it can be added to as the need arises.

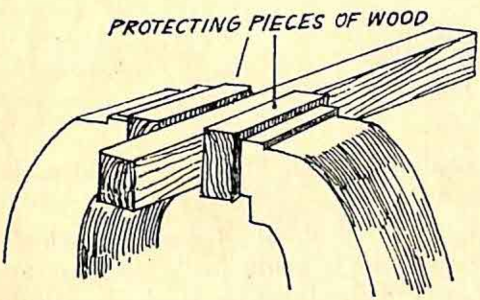


Figure 2

One item that we feel it is essential to have before many of these things is a *vice*. If a teacher is going to do anything beyond the most elementary work, a vice is required. The vice should have about 4-inch jaws and fibre grips. Even with fibre grips the jaws often mark the wood and the teacher should make a practice of not using the vice to hold wood unless he uses two old pieces of wood slipped in between the jaws and the piece of wood being worked (see Figure 2).
With this device the vice, which is really for use in metal-work, can be used for wood-work.

B Additional Tools

carpenter's brace
bit brace
set of centre-bits, augur bits, and twist drill bits

set of bits for brace ($\frac{1}{4}$ inch to $1\frac{1}{2}$ inch)
set of files (triangular, flat, round)
chisel-firmer ($\frac{3}{8}$ inch)
chisel-firmer (1 inch)
vice (4-inch jaws, fibre-lined)
oil stone
oil can
cold chisel ($\frac{5}{8}$ inch)
small wood plane
hand saw (24 inch)
hand drill (3-jaw chuck)
set of twist-drills ($\frac{1}{16}$ inch to $\frac{1}{4}$ inch in $\frac{1}{32}$nds)
grinding wheel (4-inch diameter)
centre-punch
hack-saw (10 inch)
twelve hack-saw blades to fit
spokeshave
try-square (7-inch metal blade)
two rasp files (wood)

This list could go on to include all tools, but additional tools are really to suit the individual.

One item which a good workshop should have, and which should be obtained if much work is going to be done, is an *electrically-driven hand power-tool* of the Black & Decker or Wolf variety. The basic power-tool can be purchased first and the many pieces of equipment available obtained as and when a need for them is felt.

For glass-working the following tools may be purchased:
Six triangular files
asbestos sheet
glass-cutter
fish-tail or bat's-wing burner, to suit gas supply

At a later stage a suitable pipe and foot bellows may be purchased.

Storage

Tools are made of steel and rust quite quickly, particularly in a damp climate. All tools should be wiped over fairly frequently with an oily rag; moving parts should be kept oiled.

It is worth spending time and trouble in the proper storage of

tools. All too often the science teacher's tools are thrown into a box or a drawer and suffer accordingly. Tools are best stored hanging on racks or hooks or clips on the wall behind the working-bench. The wall should have a large board fixed to it and the racks and hooks should be fitted to the board. (Some people prefer to fit 'peg-board', i.e. hardboard with lots of regularly-placed holes in it, and fit pegs and hooks in the holes. In this way alterations can be easily made to fit the tools as required.)

Each tool requires its own special fitting. Tool fittings can be made from wire clothes hangers. A hammer and a hacksaw, for instance, can simply hang on pegs, nails or hooks as can a brace.

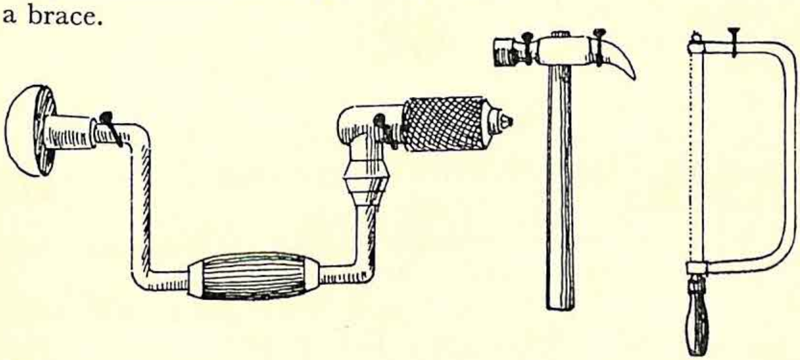


Figure 3

Saws

Cut two pieces of wood the shape of the *inside* of the saw handle, but a fraction smaller. Screw one of these pieces to a cleat on the wall using two screws. The saw will hang on this. To prevent the saw falling off, the second piece of wood should be screwed to the first piece using one screw in the middle. This acts as a thumbscrew (see Figure 4).

Do this for as many saws as you have.

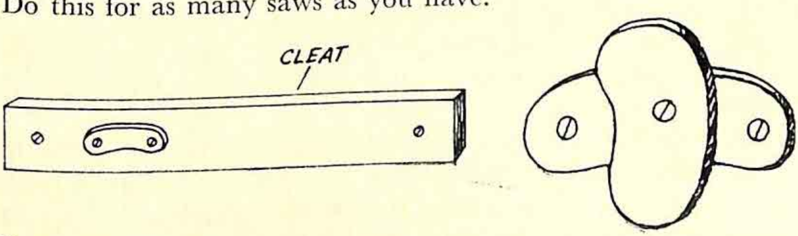


Figure 4

Chisels and files, screwdrivers, etc.

Construct racks out of wood in the shape shown in Figure 5. Screw this to the back board on the wall.

The inverted V-cuts allow the blade of the chisel, file or screwdriver to pass through, but not the handle.

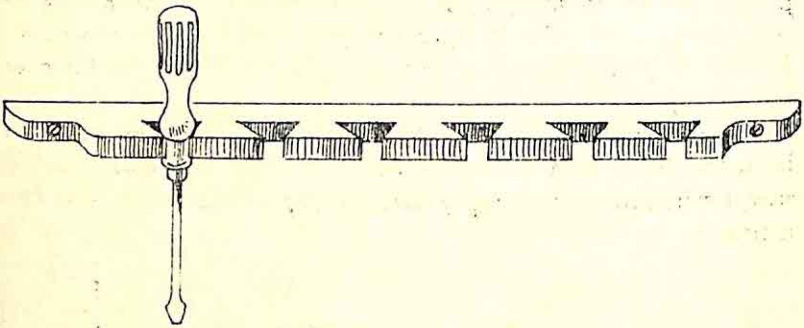


Figure 5

Bradawls are simply pushed into a hole drilled in a piece of wood.

Planes are best stored flat on a bench. Nail or screw thin pieces of wood to prevent them from slipping (see Figure 6).

Sharpening Tools

If a tool is used properly, it should not require major attention very often.

Unfortunately few of us use tools properly and since most of the tools we use for wood-work and for metal-work are for cutting, the cutting edge becomes worn and chipped, and requires sharpening.

Saws

Saws can be sharpened and set by the amateur wood-worker, but generally speaking it is easier and better to send the saw out to sharpening experts for attention. How often a saw needs to be sharpened depends, of course, on the amount of use it gets, but it is a safe rule to send out saws for sharpening at least once a year. Then normal care in use and storage will keep them in good condition. Sharpening a saw is a skilled job and an amateur's efforts can ruin one very quickly.

Chisels, planes and knives

The cutting edges of tools need sharpening fairly frequently on an oil-stone. Oil-stones are made in many different shapes and

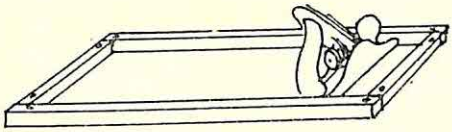


Figure 6

sizes, but the most useful kind is about 9 inches long by $2\frac{1}{2}$ inches wide. This should be fitted into a block of wood screwed to the bench as shown in Figure 7.

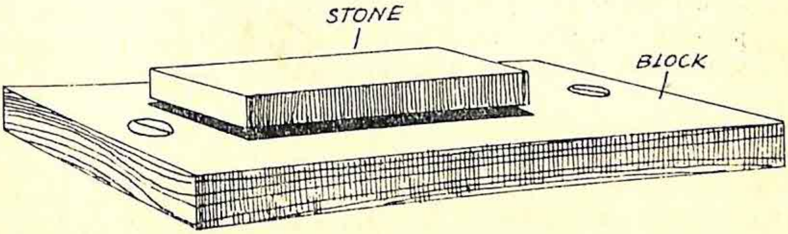


Figure 7

The oil-stone must not be used until it has been treated with a *dressing*. This dressing is made by mixing oil and kerosene. It is a good idea to keep a small oil-can full of dressing beside the block, because a thin film of dressing must be on the stone at all times. The dressing keeps the pores of the stone free from metal particles, which are rubbed off as the blade is sharpened.

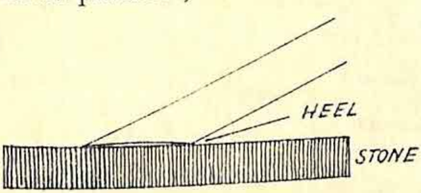


Figure 8

Whetting

Putting the final sharp edge on a tool using an oil-stone is known as whetting. The steps in whetting are as follows:

1. Place some oil-stone dressing on the stone.

2. Place the blade so that the *cutting edge* and *heel* rest flat on the stone:
3. Slightly raise the heel about 5°.

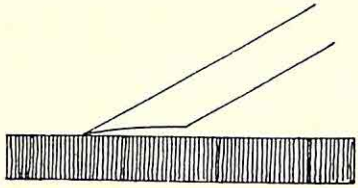


Figure 9

4. Move the blade backwards and forwards over the oil-stone in a circular or figure-of-eight motion, keeping the hands parallel with the stone. This motion wears the entire surface of the stone and keeps it flat and in good condition.

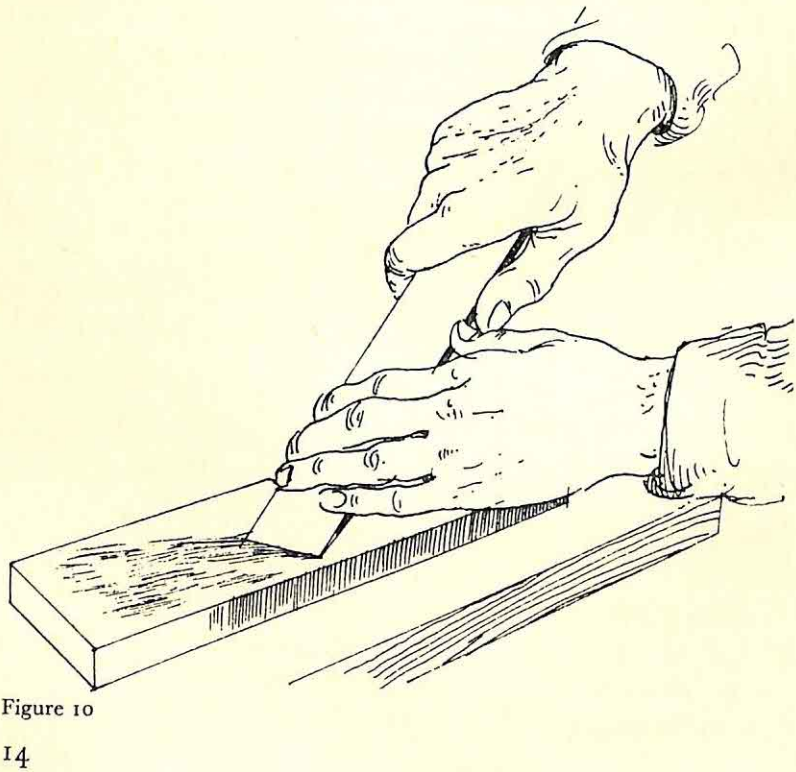


Figure 10

5. Turn the blade over, and holding it *flat on the Stone*, rub it for a short time with the same motion as before. This will help to remove the 'wire-edge'.

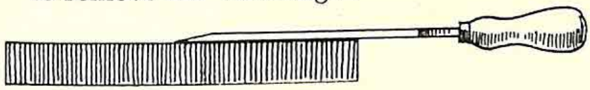


Figure 11

6. To be sure of a very sharp edge, all burrs and wire-edges must be removed. After whetting, run the blade through a piece of hard timber.

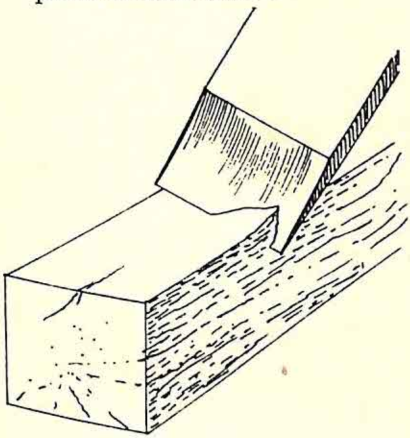


Figure 12

Grinding

If the blade becomes chipped or the proper bevel needs restoring, the edge must be ground. This should only be necessary occasionally.

N.B. Eye-goggles or an eye-shield should be worn. When grinding is complete the edge should look like this:

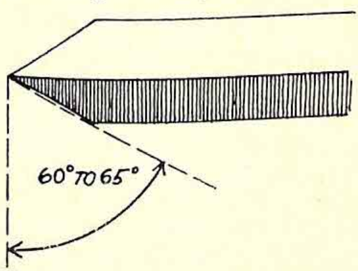


Figure 13

Notice the *hollow-ground* edge formed by the grindstone. A wood-work tool should be ground to an angle of 25° to 30°. (A rough guide to this is that the length of the bevel should be just over twice the thickness of the blade.)

Steps in grinding

1. Adjust the tool-rest so that the blade resting on it is at approximately the correct angle (25°-30°). The stone is rotated *towards* the blade.

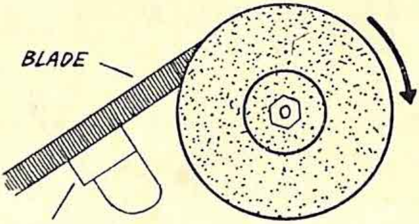


Figure 14

2. Hold the blade lightly against the rotating wheel and move it from side to side as shown by the arrows.

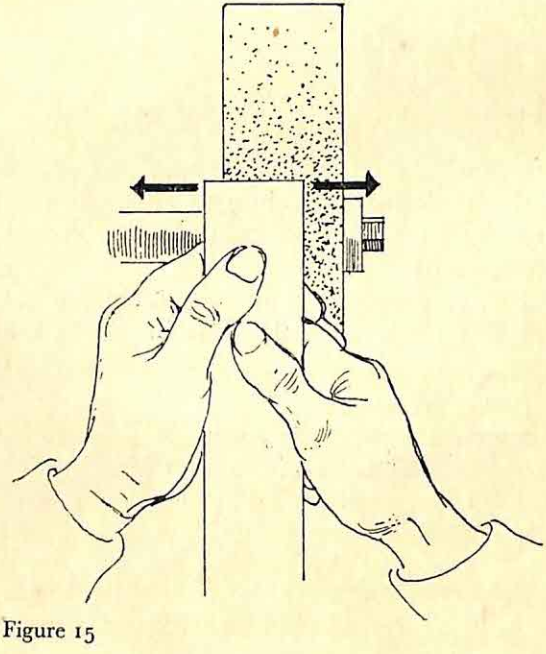


Figure 15

3. Dip the blade in water frequently, to prevent over-heating, which would destroy the tempered cutting-edge.
4. Check to see that the cutting-edge is straight and at right angles to the sides of the blade.

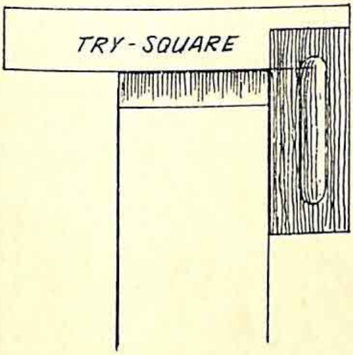


Figure 16

5. When grinding is complete, round the corners *very slightly* as shown.

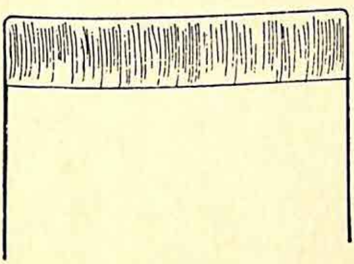


Figure 17

Protection

Tools made of steel will quickly rust and deteriorate when exposed to moist air.
All tools should be wiped over with an oily rag at frequent intervals.
The tool should be wiped clean before use and wiped with an oily rag again when the day's work is finished.

A tidy work-bench
A work-bench covered in shavings, sawdust and tools is no

longer a place where work can be done. There is often little room to work, the work is covered with dust and as the workman sweeps the mess aside he often sustains cuts and bruises. Furthermore he often sweeps his tools on to the floor or against each other, and they become damaged or broken.

A safe, sure rule is to use one tool at a time and return it to its rack *immediately after use*. Even if it is proposed to use it again shortly, this is still the best and safest procedure.

3 WOOD-WORKING

Hand-saws

Saws are designed for different purposes and are of two main kinds, *cross-cut saws and rip-saws.*
These names refer to the purpose of the saw. The cross-cut saw is designed to cut *across* the grain of the wood. The rip-saw is designed to cut *along* the grain of the wood. The following notes will help in identifying saws and understanding their construction and how they are used:

Setting

All saws cut a path through wood wider than the width of the saw blade itself. If this did not happen the blade would bind and stick in the cut made. To obtain this wider cut the teeth are '*set*' or pushed out sideways as the drawings below show. The teeth are bent alternately in opposite directions.

Cross-cut saw teeth

The cutting action is like a series of parallel *knives* a fraction of an inch apart (see Figures 18 and 19). The cutting edges are shaped almost like equilateral triangles.

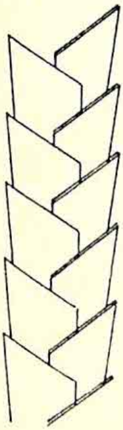


Figure 18

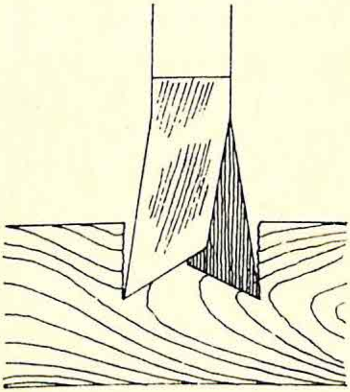


Figure 19

Rip-saw teeth

The cutting action of a rip-saw is like a series of chisels.

Using a saw

Some terms used in sawing have already been mentioned. Another you may have heard is 'kerf' which means the cut made by a saw in wood. Saws are made with varying numbers of teeth per inch. A coarse saw is one with few teeth per inch

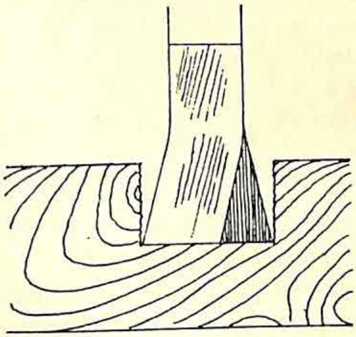


Figure 20

and large teeth. A fine saw has many small teeth per inch length. Usually the number of teeth per inch is marked on the blade close to the handle, but a quick look at a saw will tell you whether it is fine or coarse. Obviously a much smoother saw-cut is made with a fine saw.

A coarse saw is best for green, unseasoned wood.

A fine saw is best on dry, seasoned wood.

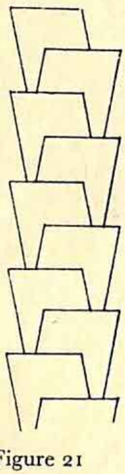


Figure 21

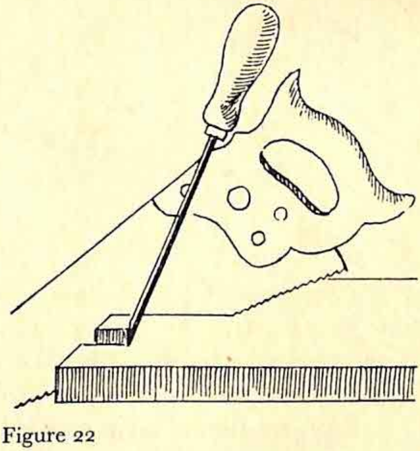


Figure 22

When sawing wood the following points are worth remembering:

1. A saw cuts only in *one* direction. Modern saws are designed to cut on the *forward* stroke and this is where the effort should be made.
2. Use the whole length of the saw. The teeth run the whole length of the saw and there is less effort in using the whole length at each stroke.
3. It is often best to clamp the piece of wood being cut, to the bench, using a 'G' clamp. An old piece of wood should be slipped between the metal of the clamp and the piece of wood being cut, to prevent marking the wood (see Figure 23).

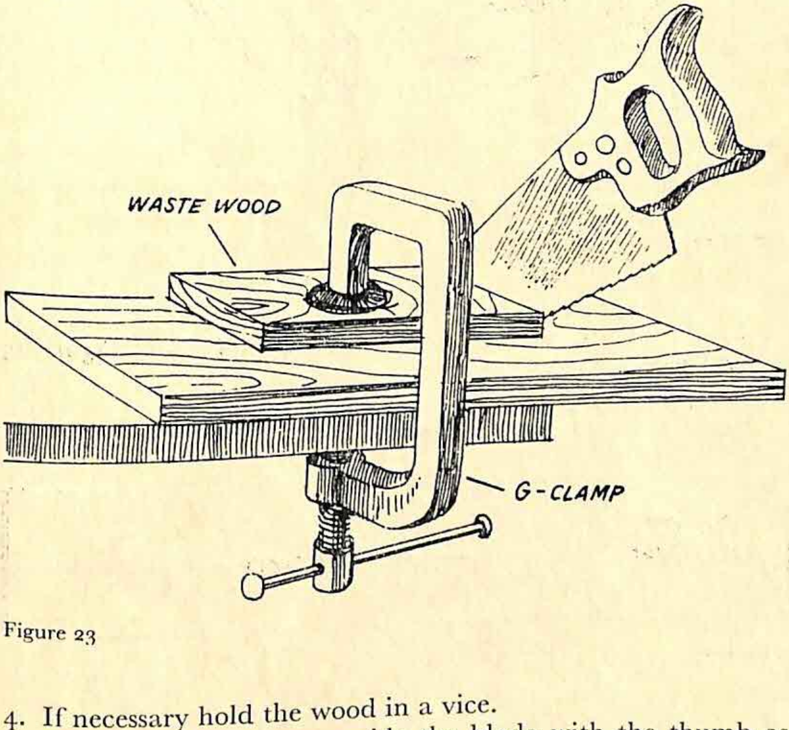


Figure 23

4. If necessary hold the wood in a vice.
5. When starting to saw, guide the blade with the thumb as shown in the figure. Always start with a backstroke.
6. Be sure to cut on the waste side of the line, allowing about $\frac{1}{16}$ inch to $\frac{1}{8}$ inch for planing and glasspapering.

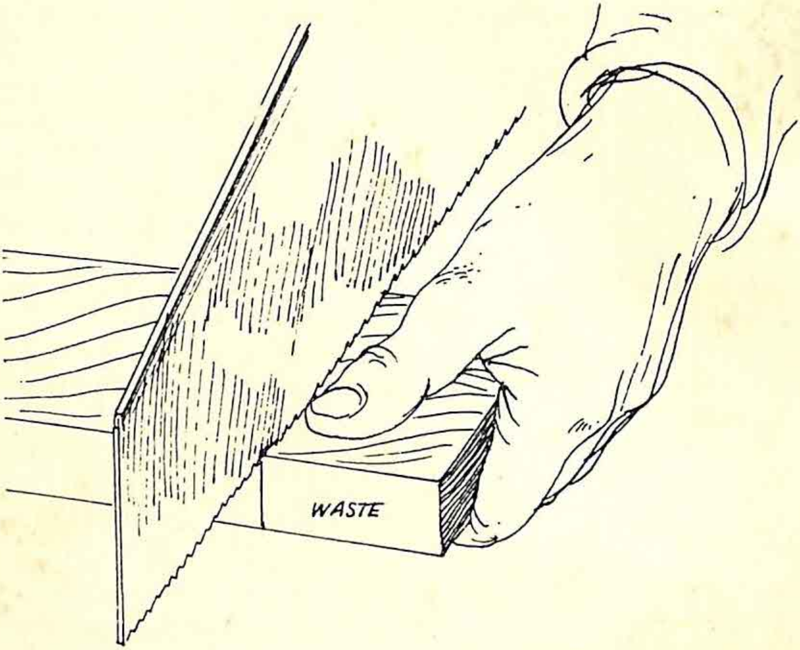


Figure 24

7. Mark out the cutting-lines on the piece of wood. Figure 25 will help you:

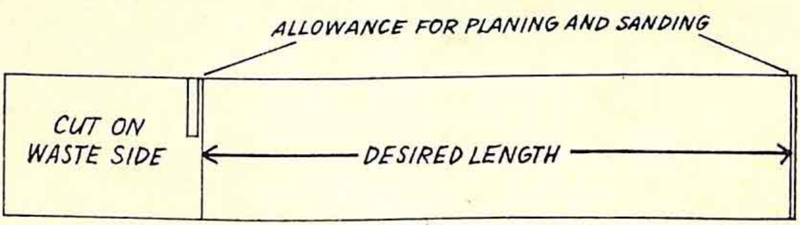


Figure 25

Common cuts and joints

The drawings following show some of the more common cuts and joints used in wood-working:

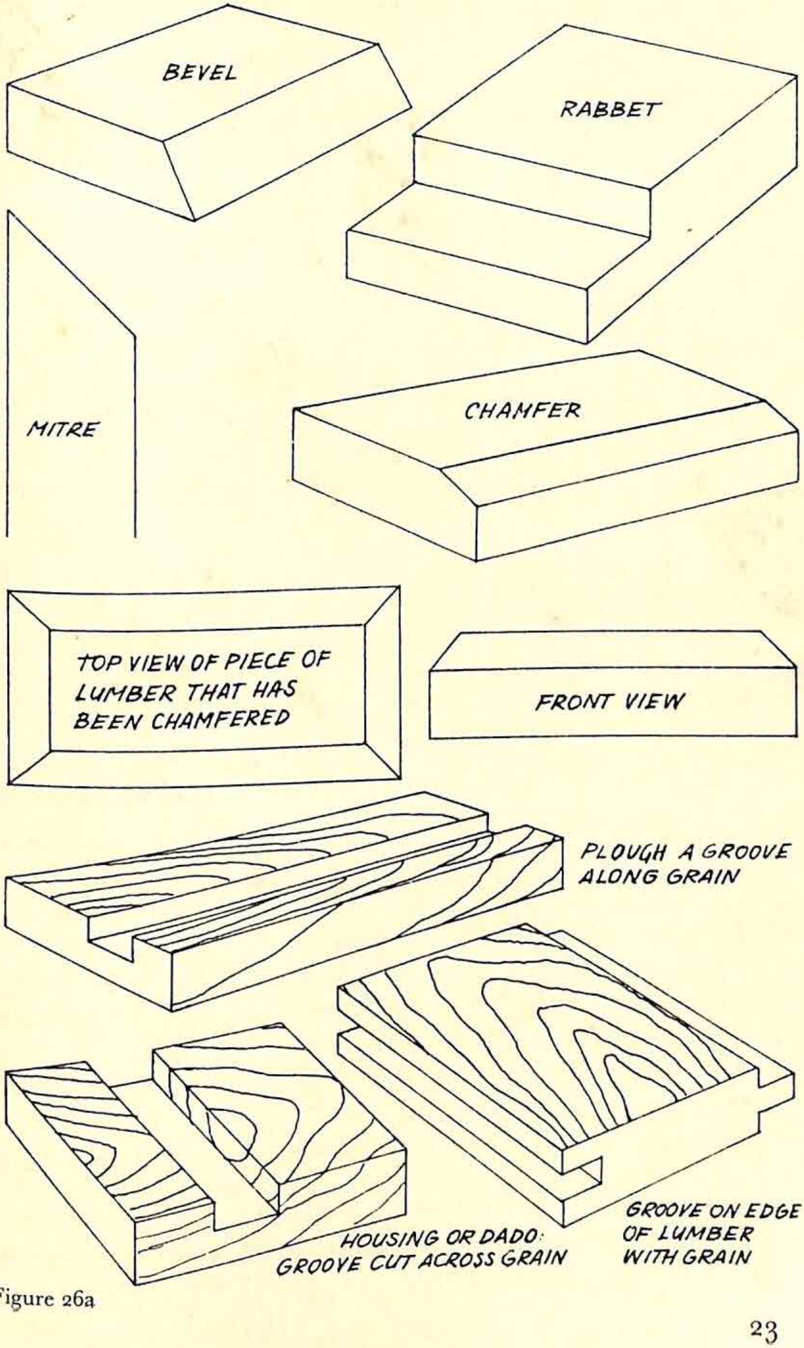

BEVEL
RABBET
MITRE
CHAMFER
TOP VIEW OF PIECE OF LUMBER THAT HAS BEEN CHAMFERED
FRONT VIEW
PLOUGH A GROOVE ALONG GRAIN
HOUSING OR DADO: GROOVE CUT ACROSS GRAIN
GROOVE ON EDGE OF LUMBER WITH GRAIN

Figure 26a

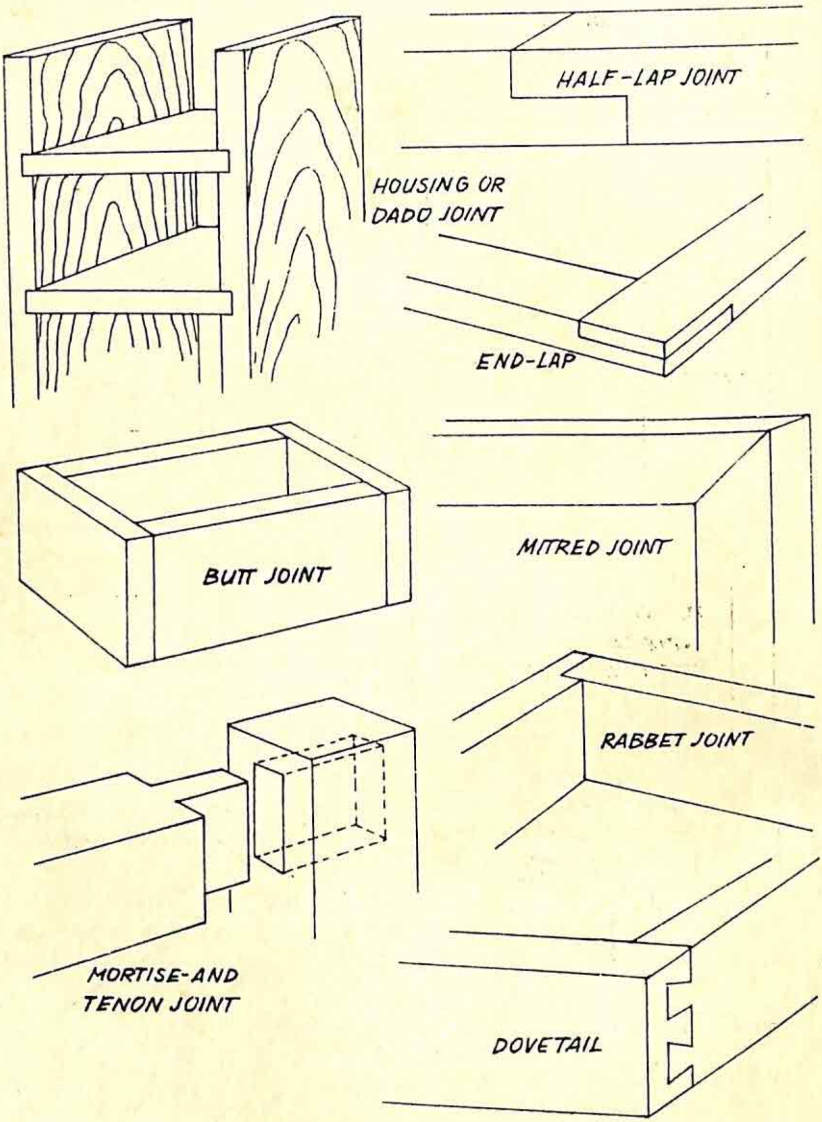

HALF-LAP JOINT
HOUSING OR
DADO JOINT
END-LAP
BUTT JOINT
MITRED JOINT
RABBET JOINT
MORTISE-AND
TENON JOINT
DOVETAIL

Figure 26b

Other Tools

The plane

The plane is used with both hands. A right-handed person puts the right hand in the handle and places the left hand at the front of the plane.

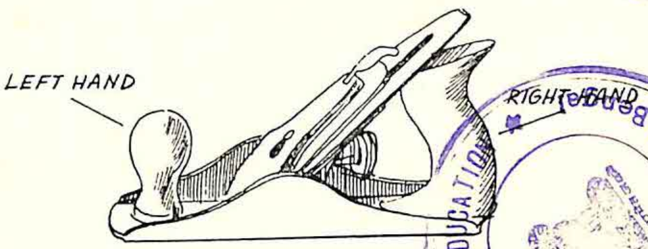


Figure 27

Both hands should work together and exert an even pressure. Occasionally keep testing the wood with the edge of a steel rule to see that you are keeping a flat surface.

When planing the end of a piece of wood do NOT drive the plane right across or you will split the wood. Plane just over half way, then reverse the wood and start from the other side.

Keep the blade well whetted and avoid all nails in the wood.

The hammer

The biggest fault people make when using a hammer is to hold it too near the head. A hammer is designed to have a handle of a certain length and if the hammer is held at the end of the handle it is properly balanced for use. The same rule applies to using a mallet.

The chisel

There are many uses for a chisel, but one rule covers all of them. *NEVER have any part of the hand or body in front of the cutting-edge.* This rule leads to correct use of the chisel and prevents the many accidents which can otherwise occur when chisels slip. Never use a metal hammer with a chisel, always use a wooden mallet. Whet chisels frequently.

Using nails

The simplest and quickest way of fastening two or more pieces of wood together is by using nails. Nails are used for numerous jobs and are manufactured in many different shapes and sizes, and in different metals, to suit the various jobs. A nail holds

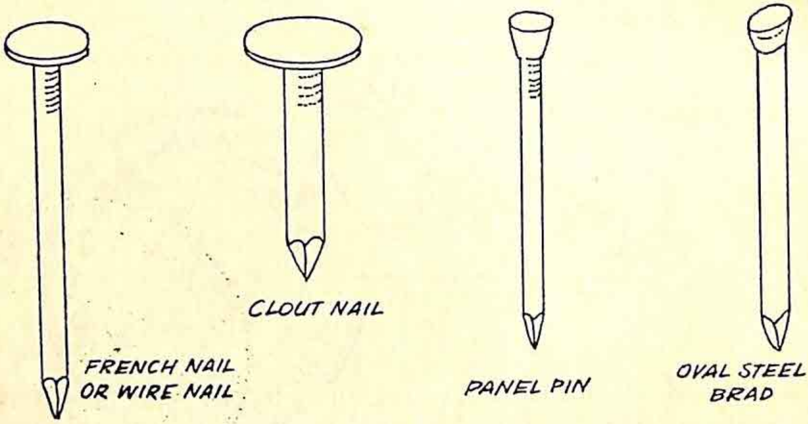


Figure 28

because the wood fibres act as small wedges and press against the nail. The rougher the surface of the nail the greater is the holding power. Figure 29 will help in understanding this.

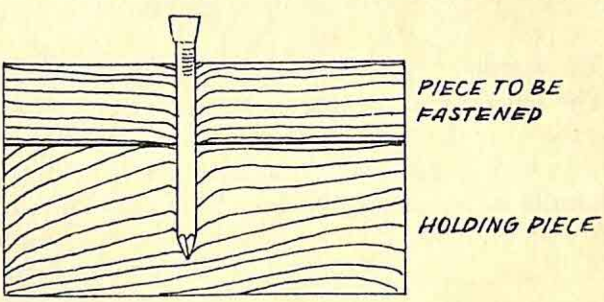


Figure 29

French nails and clout nails are used in *rough* construction work: panel pins and oval steel brads are used in 'finished' projects. Nails should never be used on any apparatus or piece of work that is subject to a great deal of movement or vibration, as the nails will work themselves loose. Nails used close to the end of

a piece of wood are liable to split the wood. A good rule to follow is that the nails should be driven into the wood at a distance from the end *not less* than the thickness of the wood.

Even so, with hard woods it is best to drill holes in the wood equal to the diameter of the nail to be used. Holes for nails can be made with a bradawl or a drill. The head cut off one of the nails can be used in the hand drill instead of a bit.

Figure 30 shows good nailing technique for butt joints, rabbet joints and many others:

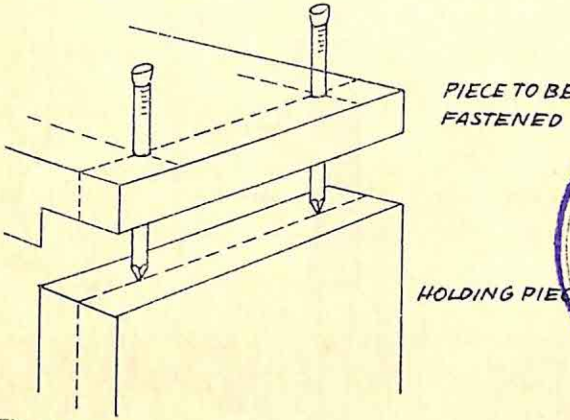


Figure 30

Dovetail Nailing (that is, driving nails in at an angle) adds to the holding power. It is best to use thin nails for this as thick ones tend to split the wood.

Never drive too many nails in the same grain line of a piece of wood. Stagger them so that no two nails are in the same grain line (see Figure 31). Too many nails driven in the

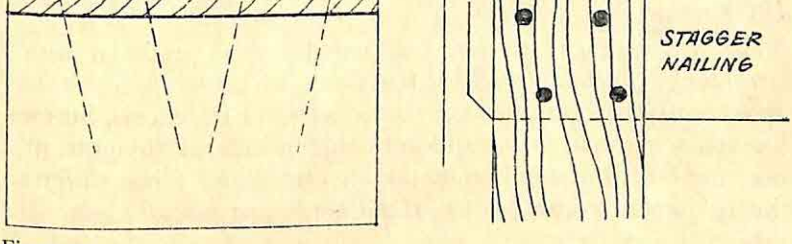


Figure 31

same grain line splits the wood. Blunting the tips of the nails also helps to prevent splitting the wood.

The length of the nail used should be from two to three times the thickness of the piece of wood to be fastened. *Always* fasten the thin piece of wood to the thick piece of wood.

Nails should be concealed in a finished piece of work. Drive the head of the nail about $\frac{1}{8}$ inch below the surface with a nail punch and fill up the hole with putty or plastic wood. Figure 32 shows how this is done.

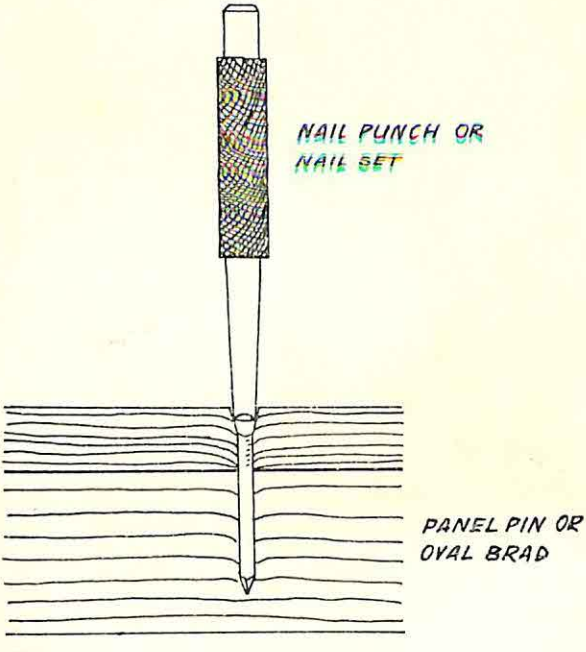


Figure 32

Using screws

Nails are quicker to use, but wood screws make a much stronger job. Woodwork held together with screws can be taken apart again without damage to the wood or the screw. Screws, like nails, come in many different thicknesses and lengths, and are made of many different metals and alloys. Two different 'heads' are in common use, *round heads* and *flat*, or *countersunk heads*.

The length of the screw is given in inches or fractions of an inch and the diameter is given in wire-gauge sizes. When fastening two pieces of wood together with screws, always fasten the thin

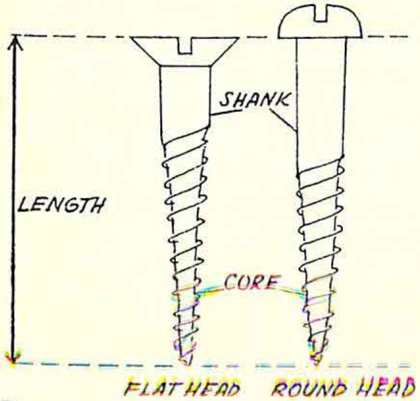


Figure 33

piece to the thick piece. For maximum holding-power the length of the screw should be from two to three times the thickness of the wood being fastened.

To prevent wood splitting, all screw holes should be drilled. Follow the procedure below:

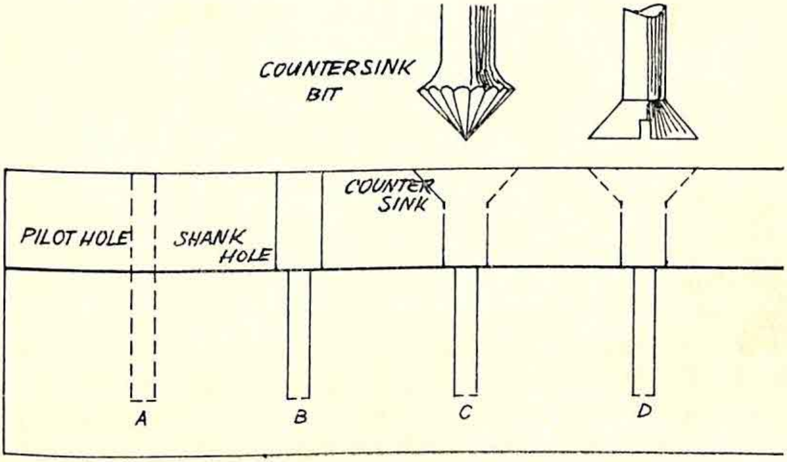


Figure 34

1. Drill a pilot hole, in both pieces of wood, equal in size to the core of the screw (A). The pilot hole should be half the diameter of the shank hole.
2. In the piece to be fastened, drill a hole slightly wider than the size of the shank of the screw (B).
3. Countersink the shank hole to take the head of the screw, using a countersink-bit as shown in Figure 34.

Using a screwdriver

It is important to use a properly fitting screwdriver. The rules applying to nails and where they should be placed apply equally to screws. Figure 35 explains itself.

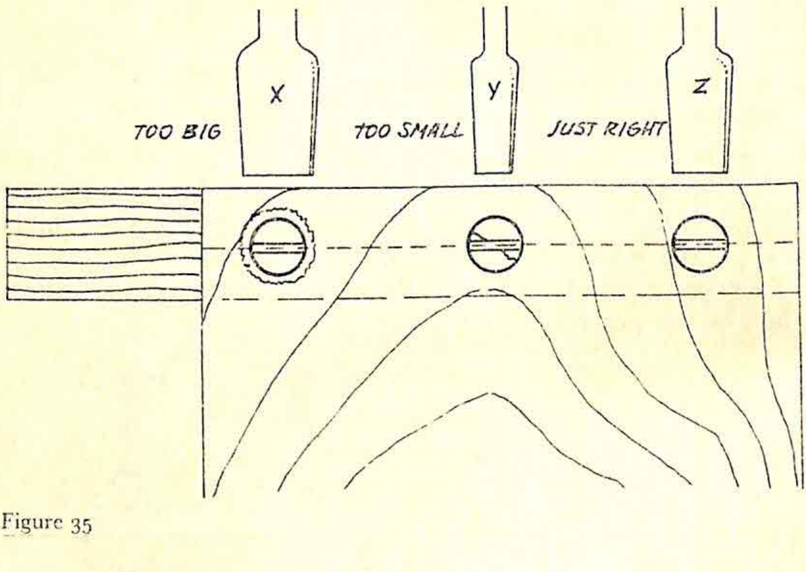


Figure 35

The nearer the screwdriver tip is in size to the slot of the screw the less chance there is of damage to either the screw or the wood. If it is too big it will scar the wood; if too small the screw head is sometimes damaged and the tip of the screwdriver broken.

Sometimes a piece of beeswax or soap rubbed on the thread of the screw reduces friction and helps in driving the screw in.

A screw should *NEVER* be driven in with a hammer.

The brace and bit

The brace is shown in Figure 36. It has two 'alligator' jaws designed to hold bits that have a 'tang'. The arris of the tang is held in the groove of the alligator jaws.

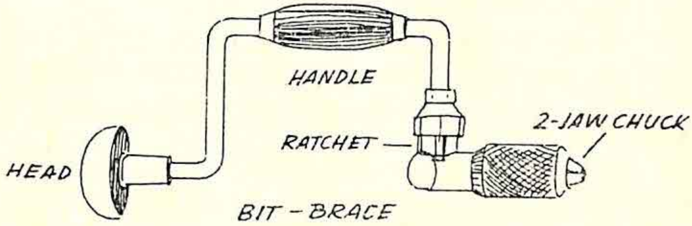


Figure 36

Some bits are shown in Figures 37 to 40. The size of bit is usually stamped on the tang.

Auger-bit

Sizes range from No. 4 to No. 16, or $\frac{1}{4}''$ to $1''$.

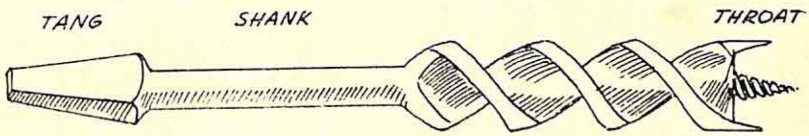


Figure 37

Twist-bit

This is designed to cut wood only. The size ranges from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch.

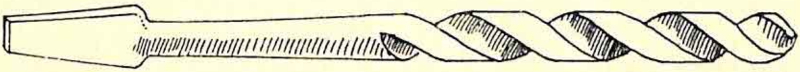


Figure 38

Expansion-bit

For holes $1''$ to $3''$ in diameter.

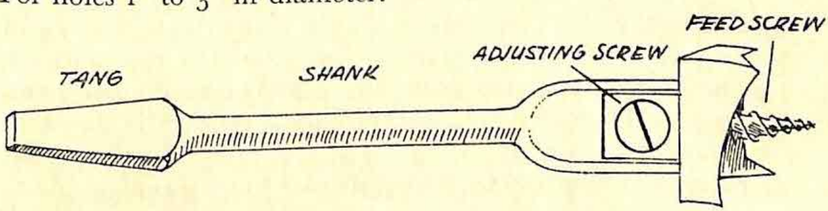


Figure 39

Forstner-bit

This is used for boring holes in end-grain or near the edge of the board, or in very thin wood. Forstner-bits come in the same sizes as auger-bits.

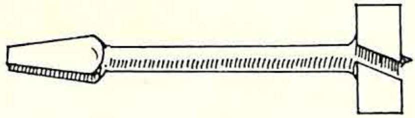


Figure 40

The action of a bit

Figure 41 shows the action of the bit. The *feed-screw* draws the bit into the wood, the 'spurs' score the wood to the exact size of the hole, the cutters act like chisels and lift the wood and the throat carries the chips away.

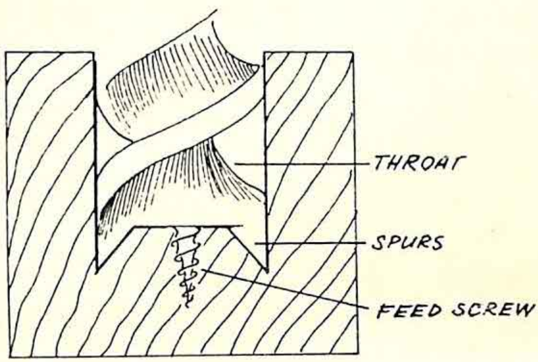


Figure 41

Drilling a hole

1. Locate and mark the exact position of the hole.
2. Mark the centre with a bradawl. This enables the feed-screw of the bit to centre accurately.
3. Clamp the wood securely in a vice. Place the feed-screw of the auger-bit into the starting hole made by the bradawl. The head of the brace is usually held against the body and supported by one hand, and the handle rotated by the other hand (see Figure 42).
4. Hold the brace and bit perpendicular to the wood and bore a hole until the feed-screw shows on the far side of the wood,

Stop at this point, turn the wood around and bore the hole out from this side (see Figure 43 A and B).

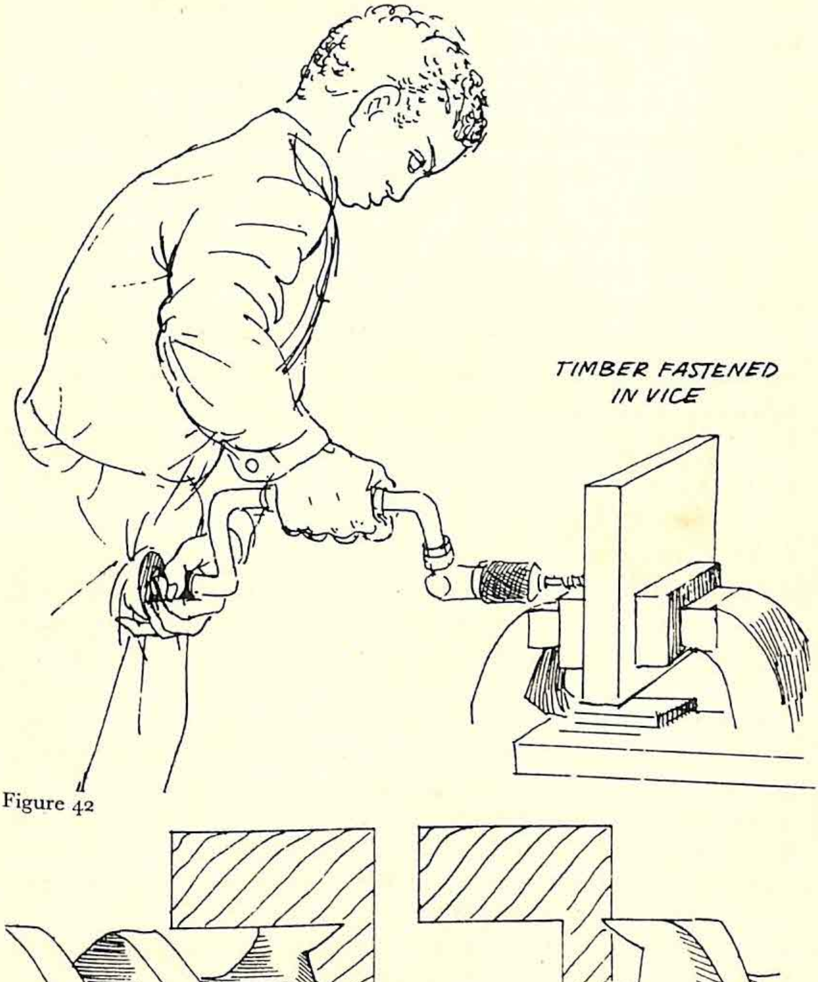


Figure 42

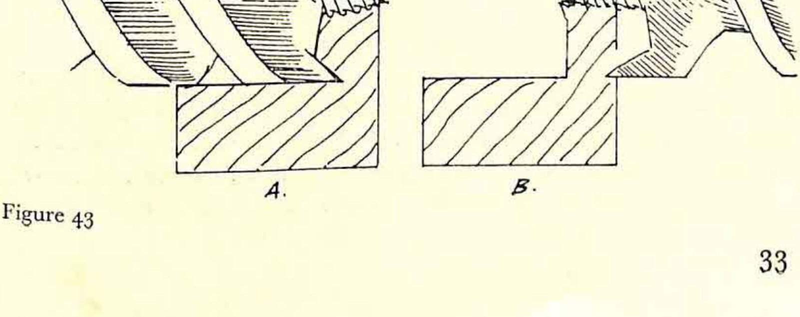


Figure 43

When boring holes in thin pieces of wood, back up (support) the wood with some heavier scrap-wood. By this method you can bore straight through the wood and into the scrap wood without turning.

Storing and maintaining bits

Bits are best stored in holes drilled in a block of wood. The holes should be large enough to take the whole of the tang comfortably.

After continued use, bits require sharpening. Unless you have had some training and practice at sharpening bits it is best to have them sharpened professionally.

Auger bits are sharpened with a specially shaped file.

Finishing an Article

When a piece of apparatus or model is completed it looks much better if it is painted, or has some other finishing coat put on it.

Paints

All paints soak into new wood, so it is best to coat the wood first with a *primer*. A primer is designed to seal the pores of the wood, and a common one in use is aluminium primer (or aluminium paint).

Many people prefer simply to finish their apparatus with aluminium paint, since this coats wood or metal and gives a pleasing appearance.

If further paint is to be used, the quick-drying *enamels* give the best results. They rarely contain lead compounds (and lead compounds turn black when exposed to hydrogen sulphide gas, which is present at times in most laboratories).

Plastic emulsion paints should generally be avoided because they tend to chip and flake off rather easily. When painting, dip only the tip of the brush into the paint and 'work it' up and down on the wood in the line of the grain.

Tins of paint, after they have once been opened, tend to form a skin when sealed again and left. When the tin is opened for use again the skin must be cut from the sides, using an old knife, and thrown away. Lift the skin out on to a piece of old newspaper, roll it up and throw it in a waste-tin.

There are many suggestions to prevent the formation of skin.

1. Pour a layer of turpentine on to the paint before sealing. (This has the disadvantage of tending to dilute the paint, since turpentine is the solvent for most paints.)
2. Before sealing the tin remove all the air with a stream of coal gas or bottled gas.
3. Store the tins upside down. If a skin forms it will then be on the bottom of the tin and the paint above can be used.

The authors have tried all these methods with some partial success, but a skin still tends to form, and it is perhaps best to accept this and simply remove it with a knife. Avoid opening the tin too frequently. Try to have two or three pieces of apparatus or models ready for painting at once.

As tins of paint get low or old, some turpentine or turpentine-substitute, sometimes called 'white spirit' should be added. Add this cautiously or the paint will become too thin. Paint must *always* be thoroughly stirred before use.

Brushes

Paint brushes must be kept clean. If painting takes place over

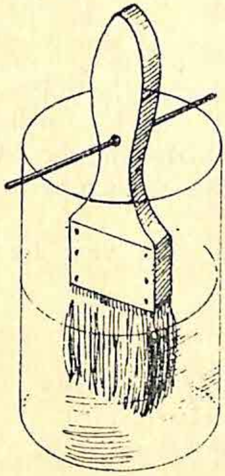


Figure 44

two or three days the brushes can be kept in turpentine or turpentine-substitute overnight. If the brushes are simply stood

in a tin or jar of turpentine the bristles will become bent and the brush useless.

Before using a brush, drill a hole in the handle so that it can be hung on a wire. When painting is finished for the day, hang the brush on the wire with its head in the turpentine, as shown in Figure 44.

When a painting job is completed the brush must be cleaned. Soak it and work it with some turpentine, wiping it periodically on old newspaper or a rag. Finally wash it with clean turpentine. Then wash the brush thoroughly with water and soap, or better still detergent, rinse it with clean water and dry it. Wrap a band of newspaper round the bristles, hold it in place with a thin rubber band (around the ferrule) and store flat.

Shellac

An ideal finish for wood apparatus is shellac flakes dissolved in methylated spirits. Shellac can also be used to insulate wires, and as a cement.

Shellac is a resinous waste-product of the *lac* insect found on the Indian sub-continent. The resin forms a shell over the insect. The shells are scraped off trees and treated, the end-product being thin, transparent flakes called *shellac*.

The solvent for shellac is methylated spirits, which evaporates quickly, leaving the shellac itself on the surface of the object. It is applied in the same way as paint, but the work must be done quickly. The first coat needs three hours to dry and should then be rubbed lightly with fine steel wool (this is much better than sandpaper and will not 'gum up').

The last coat of shellac should be rubbed with very fine steel wool.

Shellac is prepared as follows:

A. First coat: 1 part shellac, 6 parts methylated spirits
B. Second coat: 1 part shellac, 1 part methylated spirits
C. Third coat: 2 parts shellac, 1 part methylated spirits.

Note: A brush used for shellac must be stored in methylated spirits and washed in methylated spirits, NOT turpentine. It can then be washed with water and detergent, rinsed, dried and stored flat.

Hints

1. In using both paint and shellac, 'runs' must be picked up with the brush straight away.
2. *Two thin coats are better than one thick coat.*
3. Painting the bottom of a piece of apparatus is always difficult. Begin by nailing four panel pins in the bottom. *Now paint the bottom first.* Stand the apparatus upright on the panel pins (on a piece of newspaper) where it will dry quickly, and paint all the upper surface (see Figure 45). *The bottom should be finished first.*

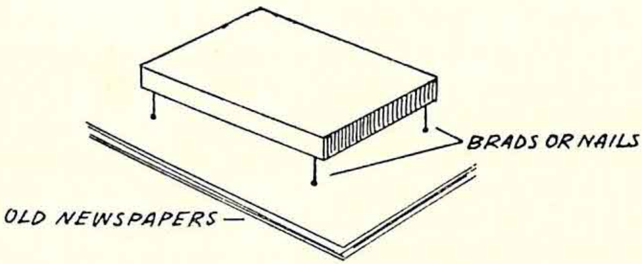


Figure 45

4. Sandpaper all wood properly before painting.
5. Avoid 'touching-up'. It is better to leave the object to dry, then sandpaper, or rub with steel wool, lightly and repaint.

4 HINTS FOR METAL-WORKING

Metal-working Tools

Tinsnips

These are probably the tools most used by the science teacher. They become blunt with time and are sharpened and set like scissors. It is advisable to have this done by a cutler. They are simple tools to use and will cut quite thick gauge metal. It is always important to mark out cuts to be made, with a pointed steel tool.

Hacksaw

Hacksaws come in many shapes and sizes and a set of blades to fit the saw should always be in stock. A large saw is used for a large job, but many of the jobs done by a science teacher can be handled easily by the small frame saw shown in Figure 46. This

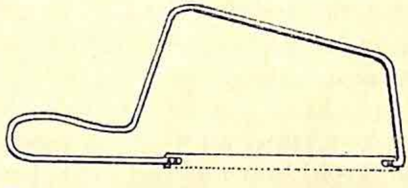


Figure 46

sort of hacksaw can be purchased very cheaply at most hardware stores, with a supply of blades.

Note: The blades of a hacksaw *cannot* be sharpened, but old blades can be used for a number of things in the workshop and laboratory and should be kept.

Drills

To make holes in metals, twist-drills are used. The point chips

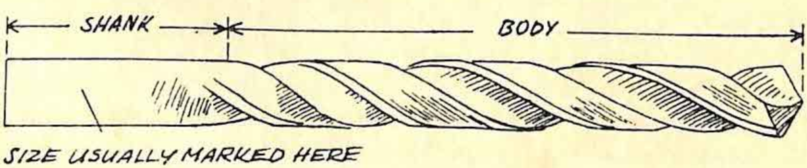


Figure 47

the metal and the flutes on the body remove the chips. The drills have the cutting lips set at an angle of 118°.

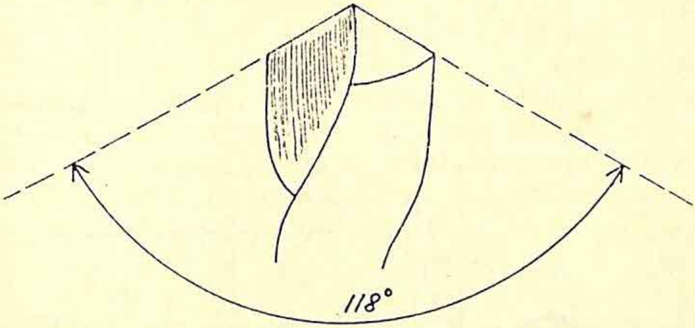


Figure 48

In time they require sharpening and this is best done by a professional, although some people prefer to sharpen their own drills on an emery wheel. It *must* be remembered that during sharpening the drill should not be overheated or it will lose its hardness. The drill should be dipped in water several times during grinding.
The twist-drill itself is fitted into a 3-jaw chuck hand drill (shown in Figure 49) or into an electric drill. Whichever is used, the technique is the same.

Hand drill

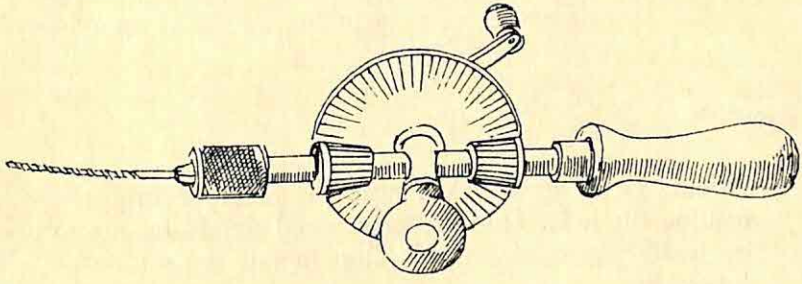


Figure 49

Drilling a hole in metal

1. Mark the centre of the hole, using a sharp-pointed metal tool (scratch awl) with a ruler and scratching two intersecting lines.

2. Mark the centre with a centre punch (see Figure 50). A slight dent should be made in the metal with a centre-punch and hammer.

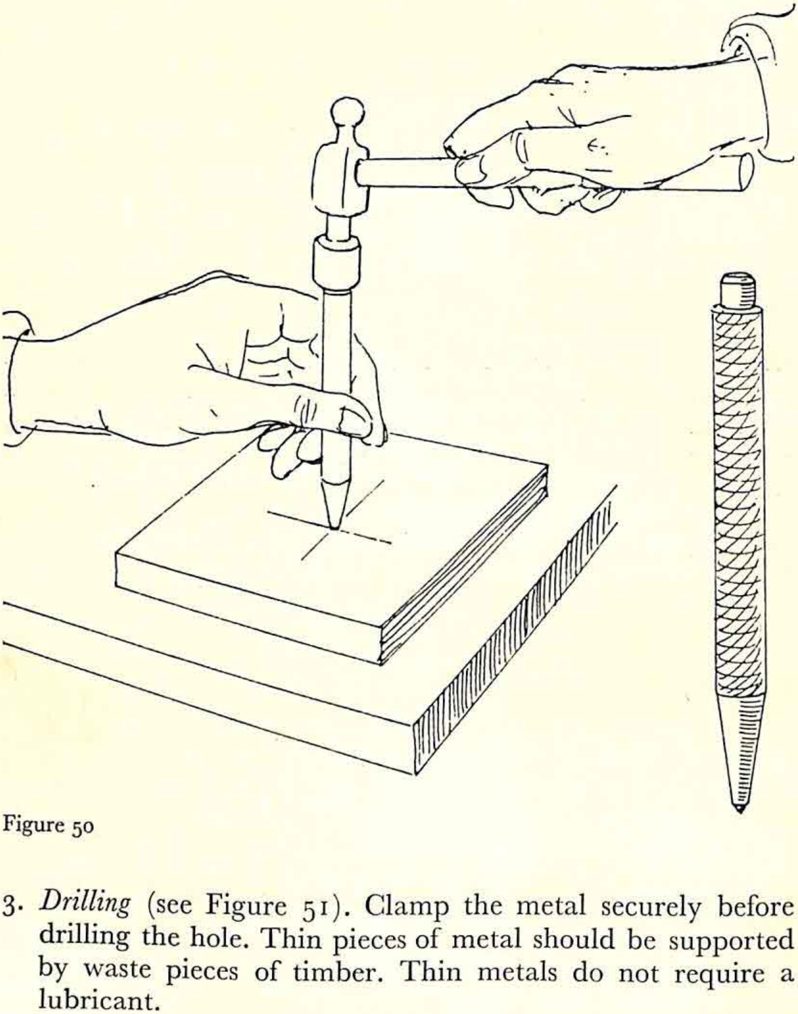


Figure 50

3. *Drilling* (see Figure 51). Clamp the metal securely before drilling the hole. Thin pieces of metal should be supported by waste pieces of timber. Thin metals do not require a lubricant.

To drill large holes

It is best to drill large holes in several steps (especially in thin metals). Drill a pilot hole first. For heavy metals be sure to use a *lubricant* to prevent the drill from overheating.

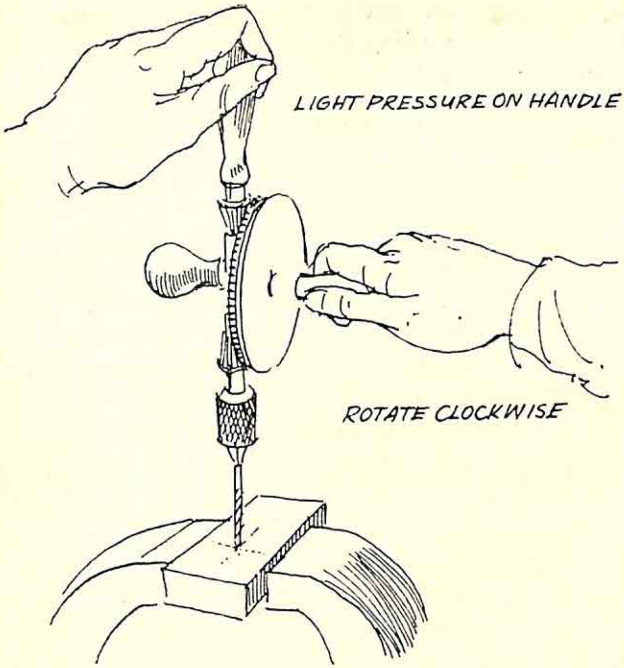


Figure 51

All work should be clamped in a vice or a clamp, particularly if an electric high-speed drill is to be used. If this is not done the drill tends to bind in the metal, which spins round, and a spinning piece of sharp metal is very dangerous.

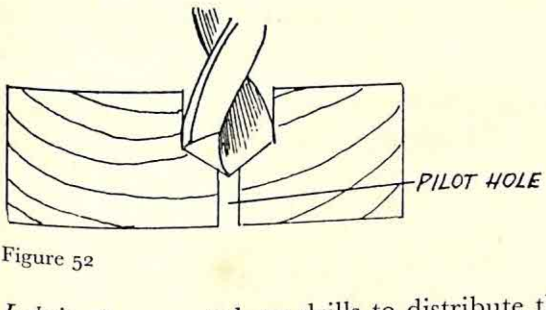


Figure 52

Lubricants are used on drills to distribute the heat. Too much heat at the point of the drill will destroy the 'temper' and the tool will then be worthless.

The following lubricants are used:

Brass	Paraffin oil
Wrought iron	Lard
Steel Aluminium	Kerosene mixed with turpentine

Cast iron does not require a lubricant.

Punching holes in sheet metal

It is quicker to punch holes in thin sheet metal than to drill them. When a hole is properly punched there are no burrs. Holes up to $\frac{1}{4}$ inch diameter are made with a *solid* punch. Punch as shown in the figure using the end grain of a block of wood or a piece of lead as a backing.

Solid punch

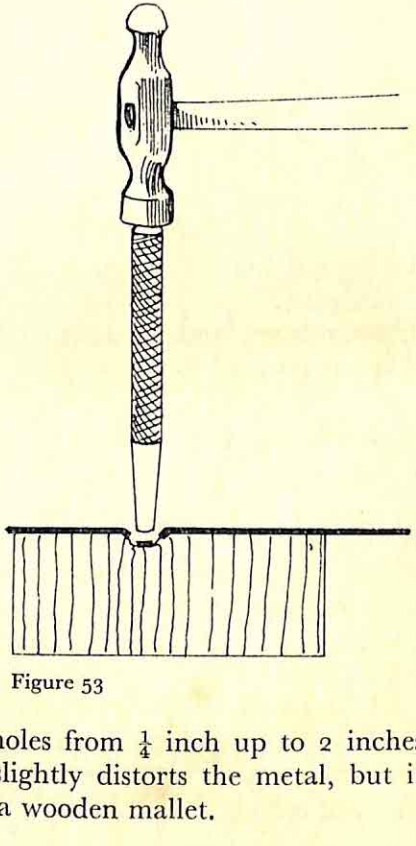


Figure 53

A hollow punch is used for holes from $\frac{1}{4}$ inch up to 2 inches diameter. Punching a hole slightly distorts the metal, but it may be flattened easily with a wooden mallet.

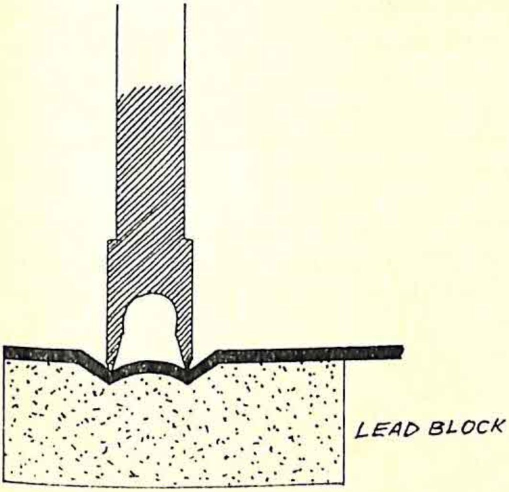


Figure 54

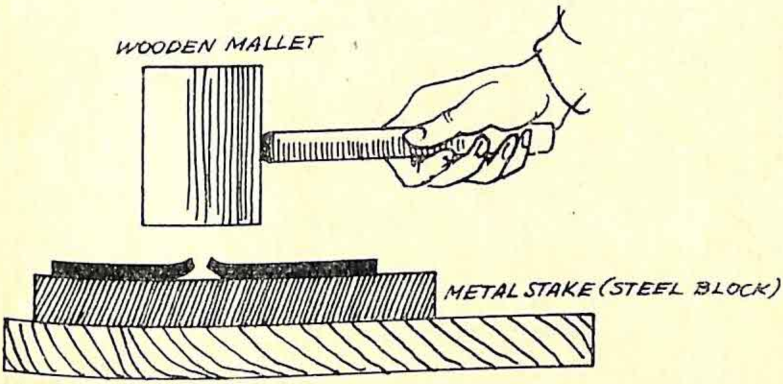


Figure 55

Sometimes a hole is a fraction too small and it is quicker and easier to ream it larger than to drill it. Use a tapered reamer or simply a tapered spike.

Cutting metals with a cold chisel

The cold chisel is a wedge-shaped tool used to cut various metals that are softer than the cold chisel. The chisel is made of carbon steel and is usually ground to have an included angle of 60° to 70°. The edge of the chisel should be slightly convex.

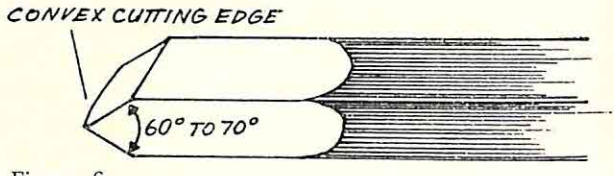


Figure 56

The metal to be cut is fixed in the jaws of the vice so that the cutting line is along the vice. The chisel will make a shearing cut. The lower bevelled edge of the chisel is laid flat on the vice (see Figures 57 and 58).

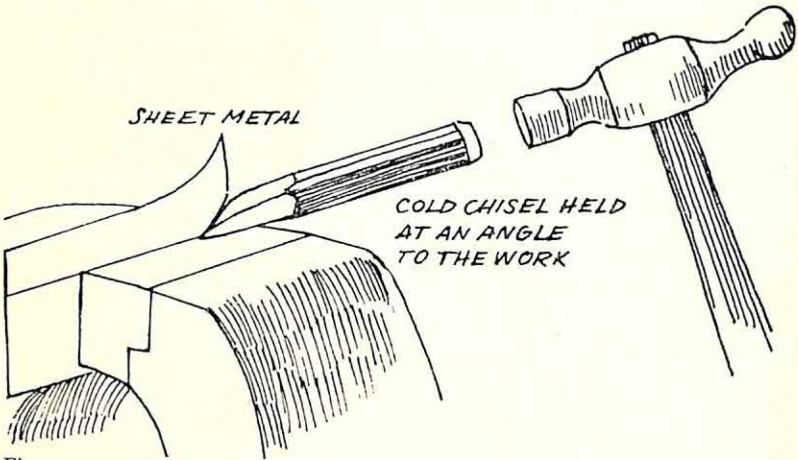


Figure 57

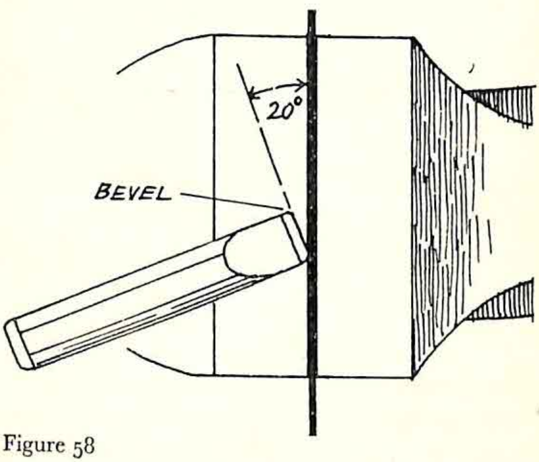


Figure 58

Ordinarily the cold chisel is held in the *left hand* with the thumb and first finger about 1 inch from the head of the chisel. Hold the chisel, at an angle of about 20° to the work, with a steady but rather loose grip with the finger muscles relaxed. This will give the best cutting action; at the same time, if you miss the head of the chisel with the hammer, the fingers will slide down and soften the blow somewhat. *Always watch the cutting edge of the chisel and not the head.*

Two pieces of angle iron can be used to protect the vice (see Figure 59). In this case the bevelled edge of the chisel rests on the angle iron.

Making an inside cut in sheet metal

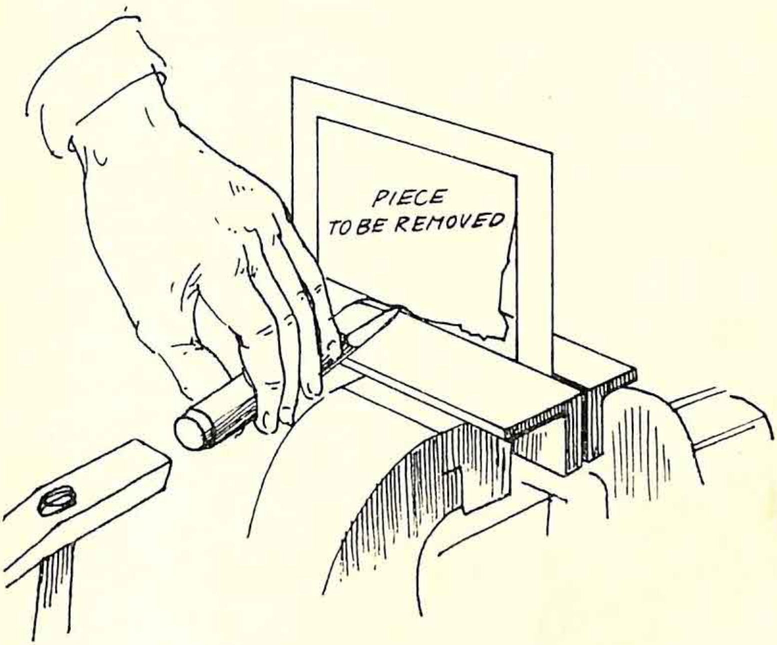


Figure 59

Other uses for a cold chisel

To remove a rivet:

First cut a groove through the centre of the head. Then cut the

head off as shown. The rivet can then be driven out with a pin punch.

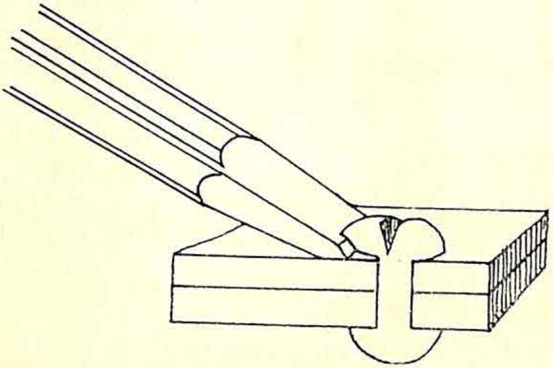


Figure 60

To remove a frozen nut:
Split the nut with a flat, cold chisel as shown.

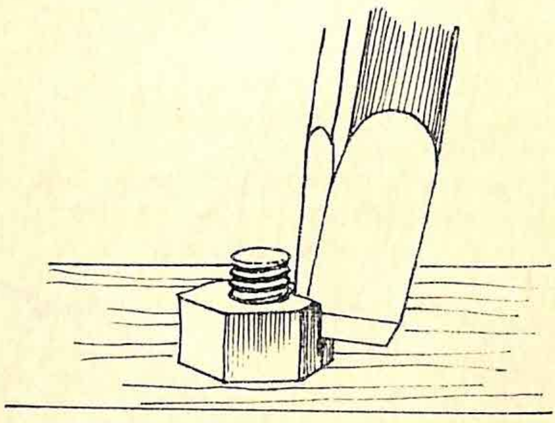


Figure 61

Care of a cold chisel

Continual use of a cold chisel causes the head to mushroom. This is dangerous for two reasons. One, the hammer slips off, and two, burrs from the mushroom fly off when the head is hammered, and can cause an injury. Using a grindstone, grind the head to the shape shown on the right of Figure 62.

The cutting edge of the chisel is ground to the correct angle and shape.

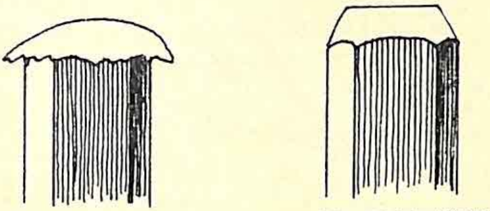


Figure 62

Files

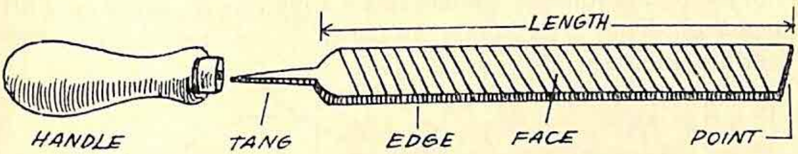


Figure 63a

Types of files

Files are for cutting small amounts of metal or for finishing a metal surface. They are made with two types of cuts, *single* and *double*.

Single-cut files have a single set of teeth at an angle as shown.

Double-cut files have two sets of teeth that cross each other.

Files are available in various degrees of coarseness. Three com-

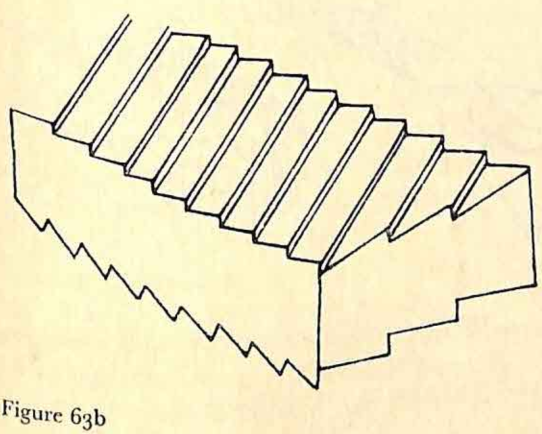


Figure 63b

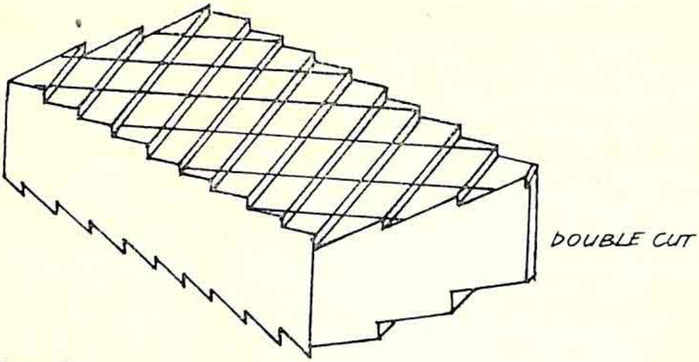


Figure 63c

monly used grades are: *bastard cut* for rough work, *second cut*, and *smooth cut*. They are available in many shapes and sizes in single and double cuts:

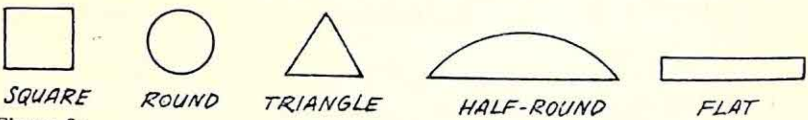


Figure 64

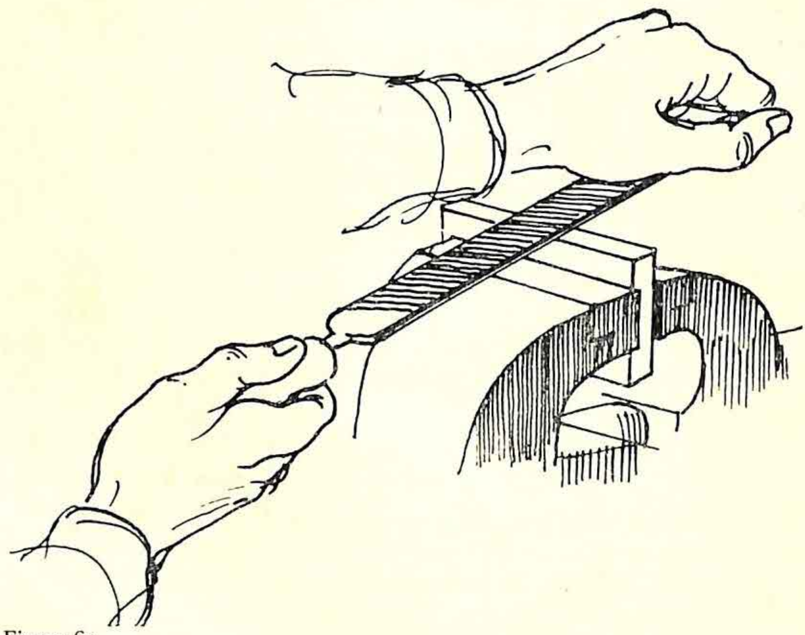


Figure 65

Rough and finished filing

1. Clamp the work securely in a vice.
2. Keep the file level but held at a slight angle to the work, and grip in the manner shown in Figure 65.
3. Apply the pressure in a forward stroke *only*, lift slightly and withdraw.
4. Test the metal being filed with a straight edge.

Draw filing

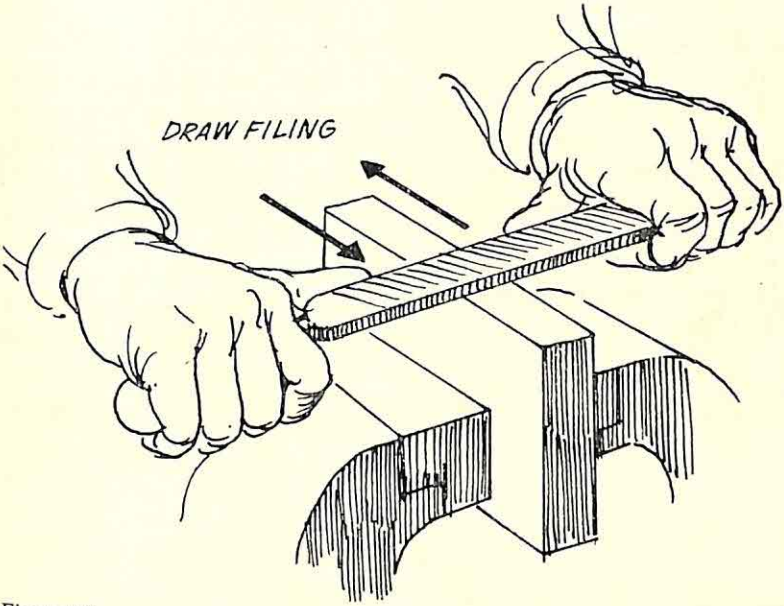


Figure 66

Draw filing is a finishing operation and is done with a single-cut file. The only care needed is in avoiding 'rounding' the edges and corners as you work.
Chalk rubbed lengthwise on the file prevents chips from clinging to the file.

Care of files

1. Clean files with a wire brush (file card). They cannot be sharpened.
2. Storage is important. Hang files in racks so that they do not

bang against other files or tools and so acquire chips and cuts that reduce their efficiency. Do not heat a file as it will destroy the 'temper'.

3. *Safety*. Never use a file without a handle on the tang. Some people think it as well to use goggles or eyeshields for filing, drilling and working with a cold chisel.

Soldering

Soldering is a quick, simple and cheap way of joining two or more metals together. The metals can be the same or they can be different.

The glue or bonding agent used is *solder*, which is an alloy of lead and tin (60 per cent. lead and 40 per cent. tin) that melts at about 450° C. This temperature is easily reached by Bunsen burners, kerosene stoves, blowlamps, etc. Solder is sold in block or wire form.

In soldering, the solder is melted and flows on to the metal joint. When it cools, it hardens and the joint is made.

The solder will not stick to metal that is dirty or coated with oxide. It is important to remember this; all work *must* be clean. Note: all metal, new or old, has a coat of oxide, because of the oxygen in the air.

Cleaning

1. Rub the surfaces to be soldered with steel wool or emery paper, or file them.
2. Spread flux on the surfaces.

Flux is a chemical which comes in paste or liquid form. It will prevent the oxide from forming or will dissolve any oxide formed.

Since metals must be heated to solder and since when they are heated the oxide tends to form, flux is essential. Solder will not bond to an oxide surface. Flux also cleans the metal and makes the solder flow more easily.

There are two kinds of flux, rosin flux and acid flux.

Rosin is an amber-coloured chemical compound obtained after the turpentine has been removed from the sap of certain trees. It is available in lump or powder form and can be dissolved in methylated spirits. Generally rosin flux for soldering is bought as a paste, in a tin.

Acid flux is sometimes known as 'killed spirits'. Excess zinc is added to hydrochloric acid in an earthenware container. After a day the liquid is strained and a small amount of ammonium chloride is added. When the ammonium chloride has dissolved the liquid is ready for use.

Generally speaking acid flux is corrosive and should not be used on radio parts or electrical connections.

Other fluxes

There are other fluxes available and it is worth investing in a tin of flux (often called *fluxite*). Rosin flux is the most used for general work.

Soldering-iron

A soldering-iron is a tool for working solder. Since it must be hot the metal must heat quickly and retain its heat. Consequently copper is chosen. A soldering-iron is made of a block of copper (called a 'bit') with a pointed tip. It is usually mounted on a rod of iron with a wooden handle (see Figure 67).

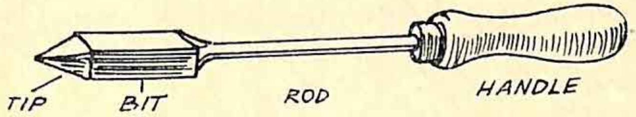


Figure 67

The copper block is made hot in the flame of a bunsen burner, spirit stove or blowlamp.

There is a danger of overheating, which spoils the bit. Electric soldering irons can be bought and they have the advantage of maintaining a steady heat. The electric soldering-iron is simply plugged in to the mains supply.

An asbestos pad should always be available on which to rest soldering-irons.

Always grasp the soldering-iron by the wooden handle. Always assume that a soldering-iron is hot rather than cold.

Preparing a soldering-iron for use: Tinning

Since the job to be soldered must be clean, it follows that the soldering-iron must be cleaned too. It must also be properly

tinned, that is, coated with a layer of solder. The steps to follow are:

1. Heat the soldering-iron in a flame (or switch on the electricity if it is an electric one) until the iron is cherry red.

Note: the electric soldering iron is *not* supposed to be heated until cherry red. Heat an electric iron until it melts a piece of solder, or scorches a piece of paper.

2. File the tip with a single-cut bastard file. For this purpose it may be clamped in a vice (see Figure 68).

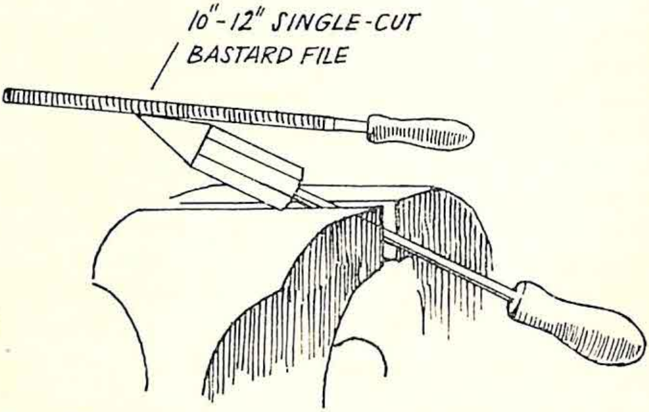


Figure 68

If you are using an electric soldering-iron *only clamp the bit in the vice.* (To clamp the sheath containing the heating element will break the element and the 'iron' will be worthless.) Alternatively, rest the tip on a brick (see Figure 69).

The tip should be the correct shape to lie flat on the metal being worked and thus to transfer its heat to the metal.

3. Re-heat the soldering-iron. After some experience you will know how much to heat it, but for the beginner there are one or two simple tests.
   (*a*) If the iron is being heated in a flame, the bit is hot enough when the flame turns green.
   (*b*) Alternatively (and for electric heating), use the 'scorch test'. Place the tip on a piece of paper. If the paper scorches, the iron is hot enough.

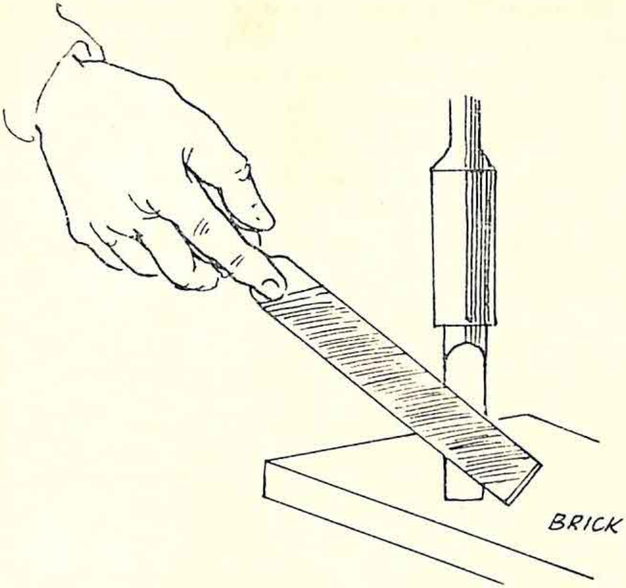


Figure 69

4. Either (*a*) rub the tip on a block of sal ammonia, or
 (*b*) dip the tip in flux paste (see Figure 70).

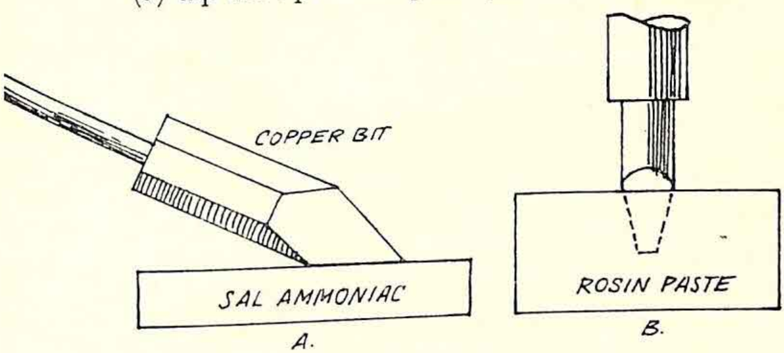


Figure 70

5. Add solder to the tip in either way shown in Figure 71.
 (*a*) Add solder to the soldering-iron tip, use scraps of solder for tinning the tip, and rub the tip backwards and forwards, using a sal ammoniac block. The solder will stick to the tip.

(*b*) If no sal ammoniac is available place some rosin flux on an ordinary brick; rub the hot clean soldering-iron tip backwards and forwards and add solder.

If the tip is clean the solder will adhere.

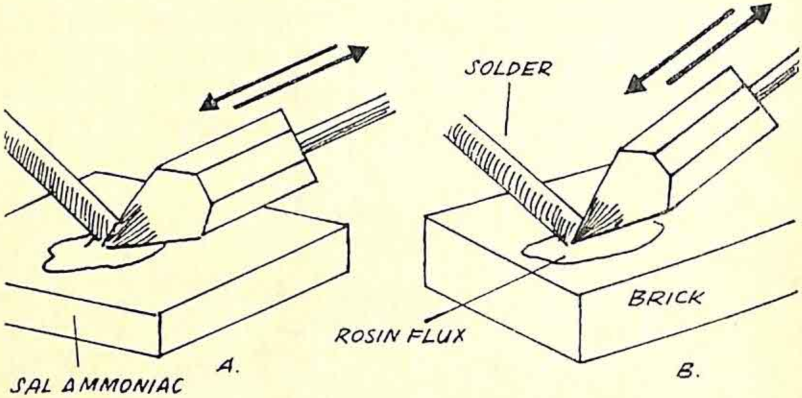


Figure 71

Be careful not to overheat the copper, as this oxidizes and corrodes the tip.

The tip will oxidize in normal use and it can be cleaned very easily by momentarily dipping the hot tip into a solution of sal ammoniac and water.

Simply dip the tip: do not soak it for any period of time or it will cool off.

Soldering

Having prepared the work and the soldering-iron you are now in a position to start soldering.

1. Heat the iron up to the proper temperature.
   (NOTE: Many people prefer to have two prepared soldering-irons: one in use and one being heated.)
2. Place the cleaned metal on an asbestos board and apply flux to the surfaces to be soldered.
3. Tack solder in several places as shown in the figure, holding the pieces of metal together with a file or screwdriver. (Not your fingers!)

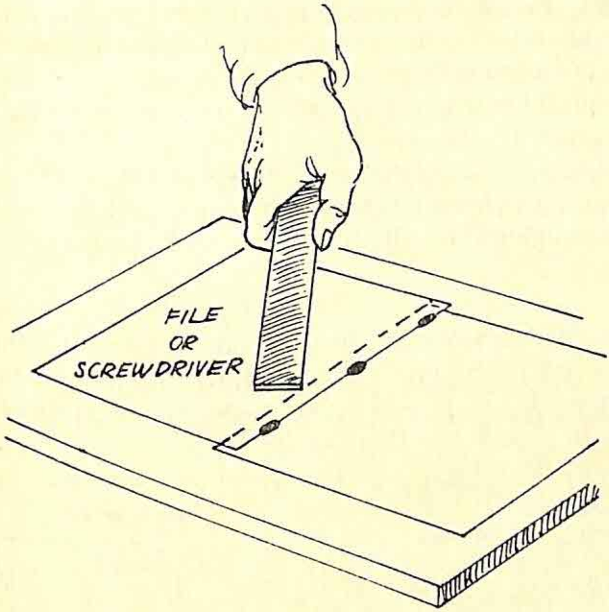


Figure 72

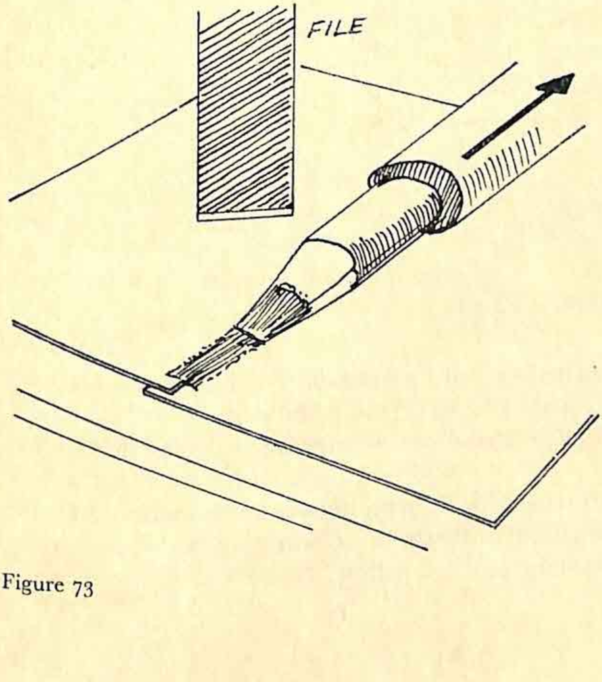


Figure 73

4. Place the hot, tinned soldering-iron at one end and hold it there until the metal gets hot enough to make the solder flow like water. Draw the iron *slowly* along the seam.

   Each tack of solder acts as a reservoir to continue the flow. Add more solder if necessary.

The solder will flow between the metals being joined.

Hold the metal together with a file or screwdriver all the time until the solder solidifies (usually it loses its lustre as it does so).

Some joints

Much of the soldering work can be done on tinplate cut from old cans if the tin is properly cleaned. Many articles can be made such as funnels, overflow cans, boxes, etc. Figure 74 shows in diagram form some joints that can be used:

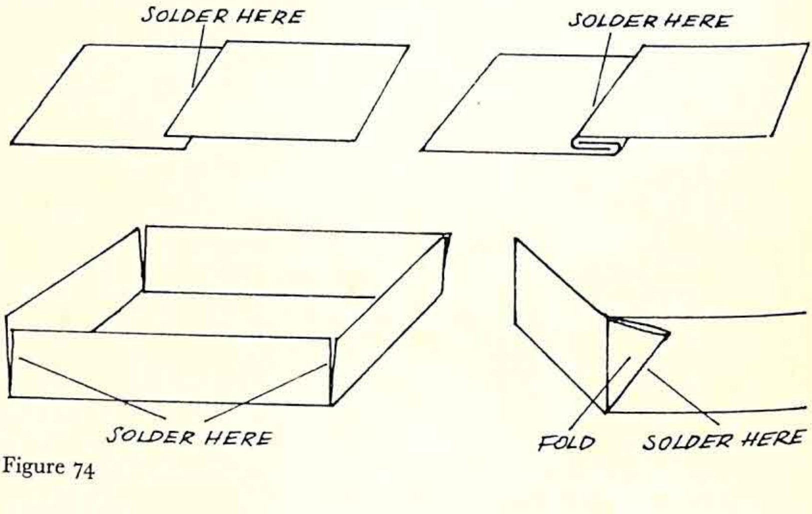


Figure 74

Soldering wires

It is a good idea to 'tin' the wires before soldering.

1. *Wires to metal plate*

   Follow exactly the same procedure as for two plates.

2. *Wire to wire*

   Hold the tinned soldering iron *underneath* the wires.

   Hold it in position until the wire is hot enough to melt the solder. Add solder and let it flow.

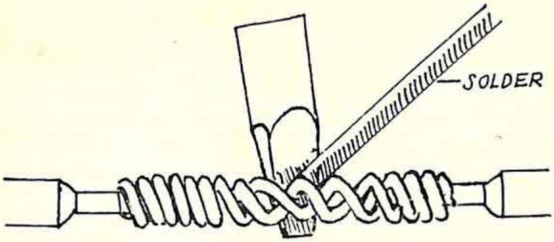


Figure 75

3. *Wire to a terminal*

Hook the wire into the hole.
Press the iron to the joint and hold the wire and lug or terminal until it is hot enough to melt the solder. Add solder.

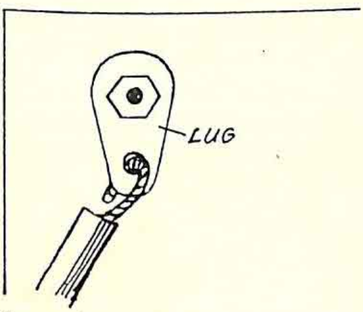


Figure 76

NOTE:

(1) All work must be clean.
(2) The soldering iron must be properly 'tinned'.
(3) Always use the *minimum* solder at all times.
(4) Practice is necessary for success.

Flame soldering

The soldering-iron is a device for transferring heat to the object to be soldered. Its other purposes are spreading the solder, holding a small reservoir, etc. Consequently a direct flame can be used for soldering.
The object is prepared and coated with flux. The solder stick or wire is held on to the joint and a flame directed at the junction of the solder and work.

Figure 77

A bunsen burner can be used for this. The flame is quite a large one and is unsuitable for small fine work.
For fine work a spirit blowlamp is used. This is a convenient tool to handle and ideal for soldering electrical wiring.

5 GLASS-WORKING

In making science apparatus it is often necessary to cut a piece of plate glass. The following notes may be of help.

The Glass-cutter. (This costs about three shillings.)
The glass-cutter does not actually *cut* glass. It has a small, extremely hard wheel which revolves as the tool is drawn across the glass. As the wheel revolves it scratches, or scores, a line across the glass. The glass is then weak along the scored line and can be broken along it.
The tool should be kept in good condition. After use it should be dipped in an oil-kerosene mixture and wrapped in an oily rag.
Just before scoring the glass with the tool, dip the cutter in turpentine; this aids the cutting operation.

Cutting Glass

1. Wipe the glass clean with a turpentine rag.
2. Spread several layers of newspaper on the bench to act as a pad. This helps to equalize pressure and prevents breakage occurring in the wrong place.

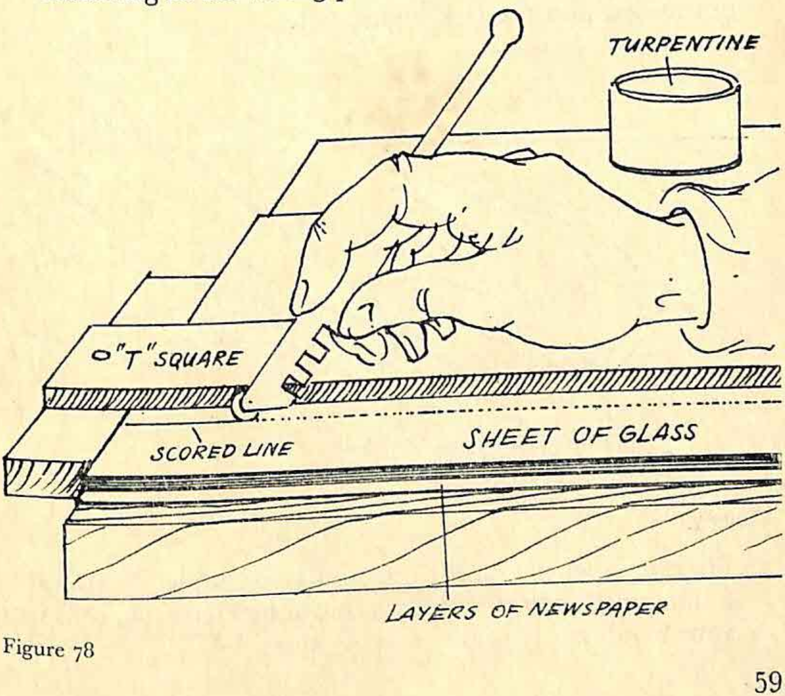


Figure 78

3. Mark the cut to be made with a glass-marking pencil (a ball-point pen will probably serve).
4. Use a T-square or meter ruler as a guide stick. Place the T-square about $\frac{1}{16}$ inch to $\frac{1}{8}$ inch from the line, to make allowance for the thickness of the frame of the cutting wheel. Practice will show you where this is.
5. Grasp the glass-cutter between the first and second fingers and support it from behind with the thumb, or hold it pencil-fashion, whichever feels more comfortable.
6. Dip the wheel in turpentine and draw the cutter towards you, using enough downward pressure to score the glass. (Practice is necessary.)
   The scored line must be continuous from edge to edge (see Figure 78).

Breaking the glass

This is done in a number of ways:

1. Place the scored line (score-side up) directly over the edge of the table. Holding the glass in position with one hand, grasp the projecting section with the other and apply a firm downward pressure (see Figure 79).

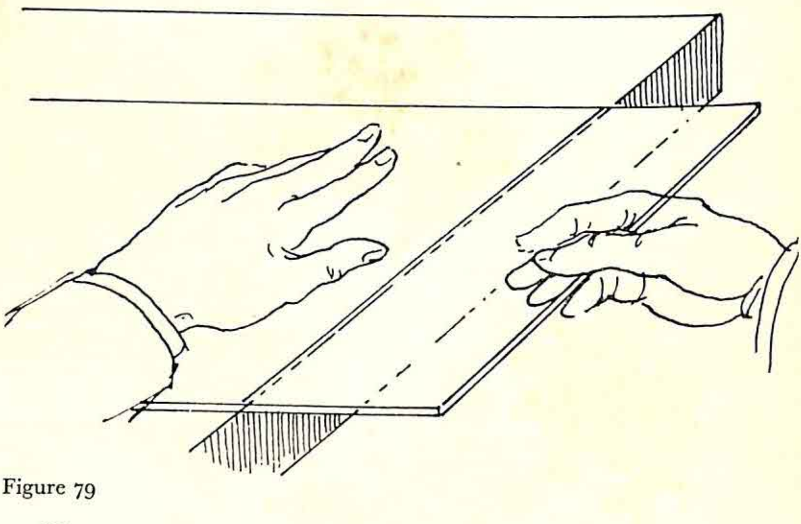


Figure 79

2. Place a paper match-stick or similar-sized piece of wood or a thin ruler *under* the glass as shown in Figure 80, and with your hands apply pressure to the glass.

3. *To remove narrow strips of glass*

Place the scored line along the edge of the table. (A square-edged and *not* a round-edged table must be used.) Use the notches on the frame of the cutter, as shown in Figure 81.

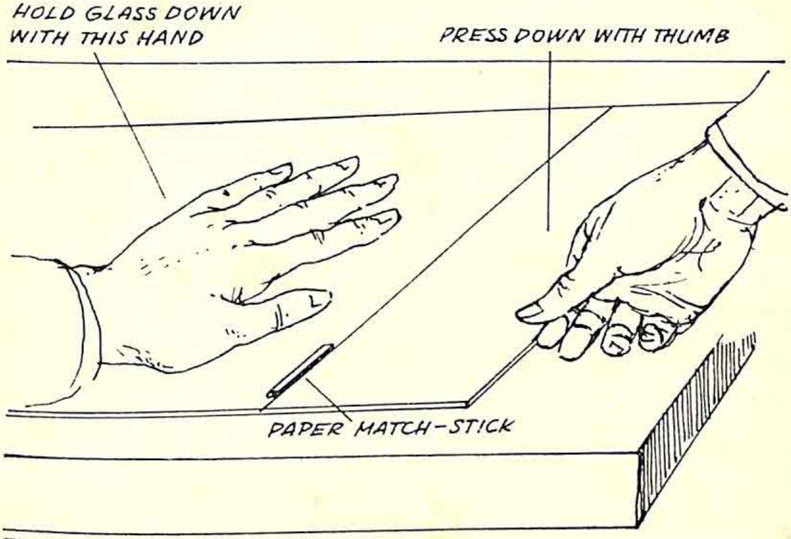


Figure 80

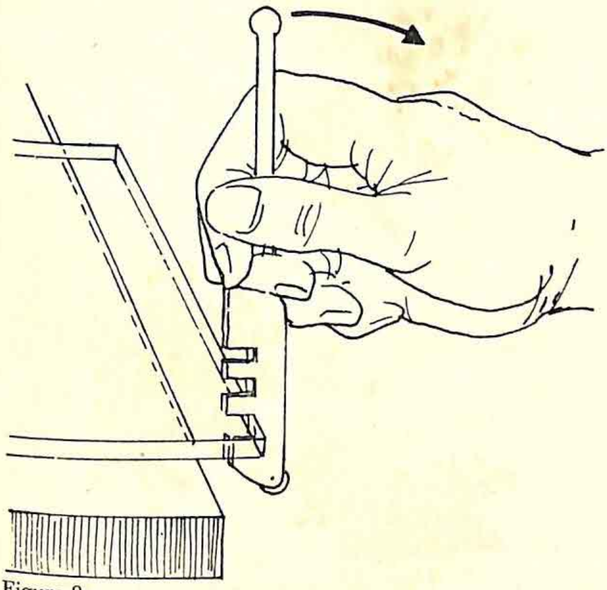


Figure 81

To remove sharp edges of glass left after the cut, rub the edges with heavy wire gauze or an emery stone or a piece of emery cloth wrapped round a block of wood.

Cutting circles or curves

1. Score the shape desired.
2. Score a series of lines tangential to the curve (see Figure 82).

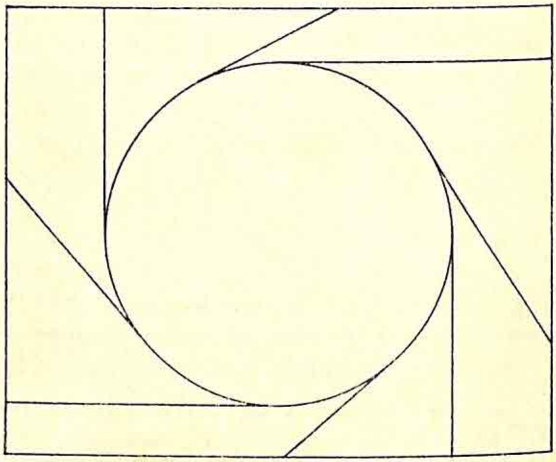


Figure 82

3. Turn the glass over with the *scored side downwards* on the bench.
4. Using the ball found on the end of the cutter, tap the glass gently. Tap on the waste side of the scored line. The glass will crack along the scored line. Remove the sections of glass that crack off.
5. Remove all sharp edges with a heavy wire gauze or emery cloth as before.

Drilling a hole in glass

A hole can be successfully drilled in glass using a home-made drill constructed from a triangular file. The end of the file is ground to a skew tip on a grindstone.
First grind a skew tip at an angle of 30°. When this is done grind a bevel on each side at an angle of about 60° (see Figure 83). Dip the tip in water frequently when grinding, to prevent over-

heating. Several drills may be made out of one triangular file. Before using, and frequently when in use, whet the tip on an oil-stone.

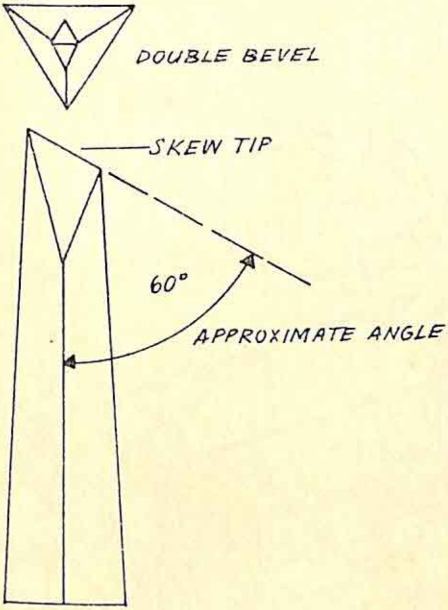


Figure 83

1. Fasten the 'skew tip' glass drill into the chuck of the brace.
2. Place the glass on several sheets of newspaper.
3. Locate and mark the position of the hole using a glass-marking pencil.
4. Place the point of the skew tip on the glass and turn slowly, applying slight pressure.

NOTE: Add turpentine as you *see and hear* the hole being drilled. Do not stint on the use of turpentine; add plenty as a coolant.

5. When the hole is nearly finished, turn the glass over and drill from the other side.

Be sure to have a flat solid surface. Use several layers of newspapers which will help fill any irregularities in the flat surface. Swinging the head of the brace in a circle helps a great deal in the drilling of the hole.

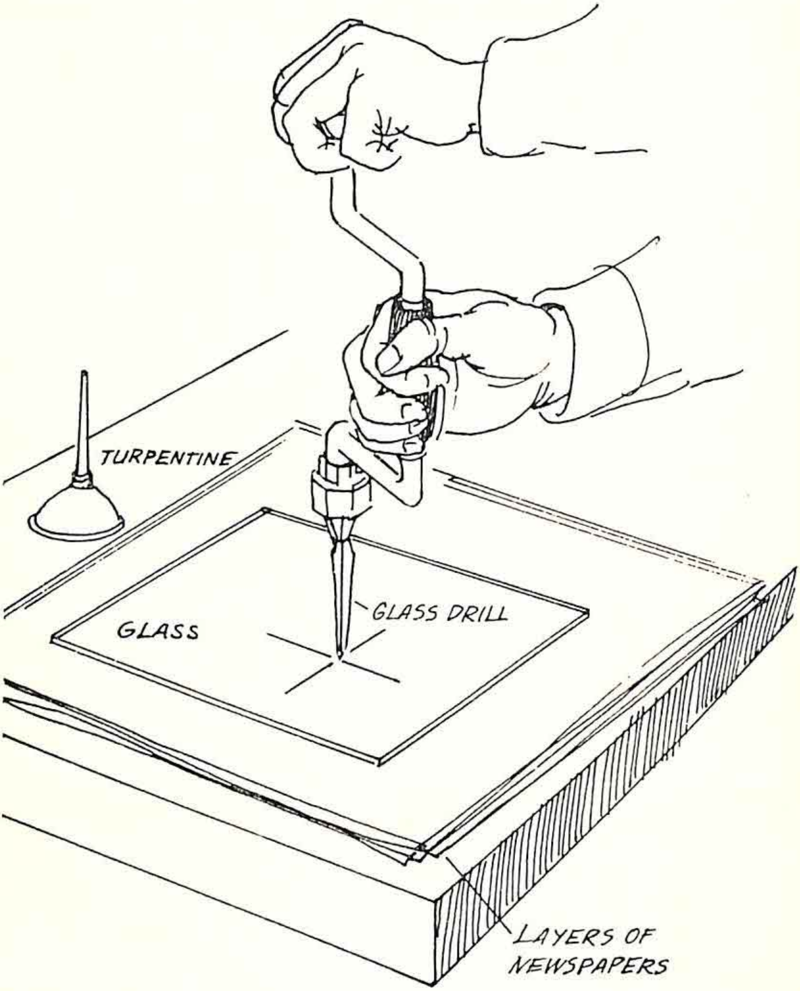


Figure 84

Bottles may be drilled in the same way. Clamp the bottle firmly in a vice, using rags or paper to protect the bottle.

Cutting bottles and wide glass tubes

Most people find difficulty in cutting bottles and wide glass tubes. The following piece of apparatus can be made easily, and if the instructions are followed strictly there should be no difficulty.

The bottle and tube scoring device is made up of 1 inch thick wood (see Figure 85).

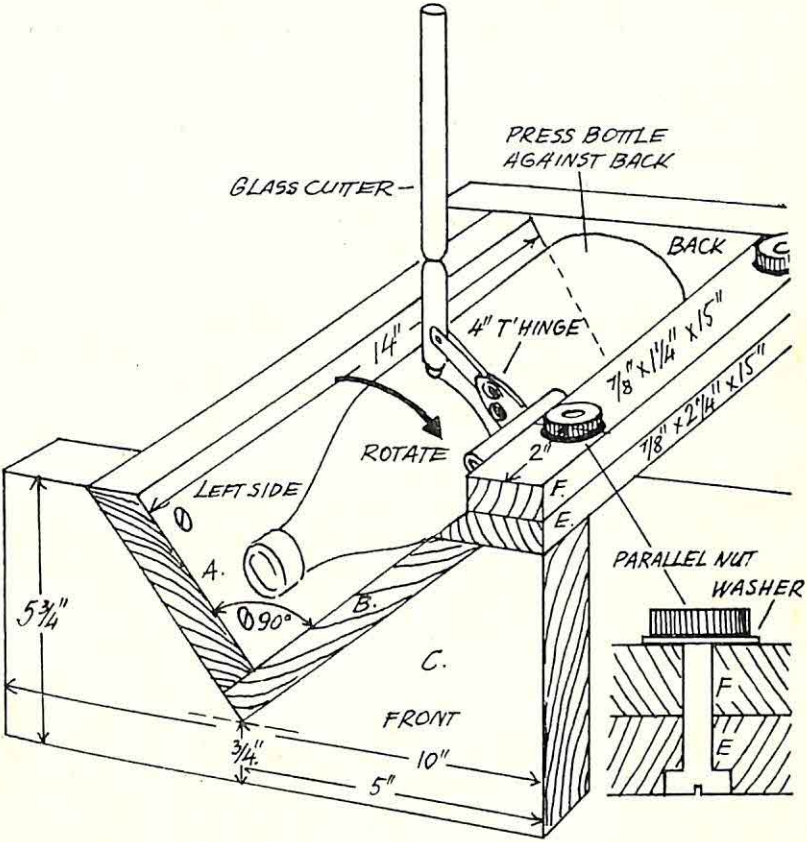


Figure 85

Though the exact sizes are not critical the pieces must fit.

1. Cut left side A and right side B and use 2-inch nails to fasten them together.
2. Cut part C to fit A and B and screw on.
3. Fit back D with nails or screws.
4. Cut part E to shape and fix as shown.
5. Fix part F above E by means of two machine bolts and nuts as shown.
6. Twist a 4-inch T-hinge to shape, drill it, and fasten a glass-

cutter on. The hinge should be clamped between wooden pieces E and F in the place required.

The bottle-scoring device is now ready for use.

1. Place the bottle or tube to be cut in the V cradle of parts A and B.
2. Move the cutter to the desired position.
3. Press the cutter against the bottle with one hand and rotate the bottle with the other.

One of the easiest ways to cut the scored bottle or tube is shown in Figure 86. The heat conducted by the copper will crack the glass.

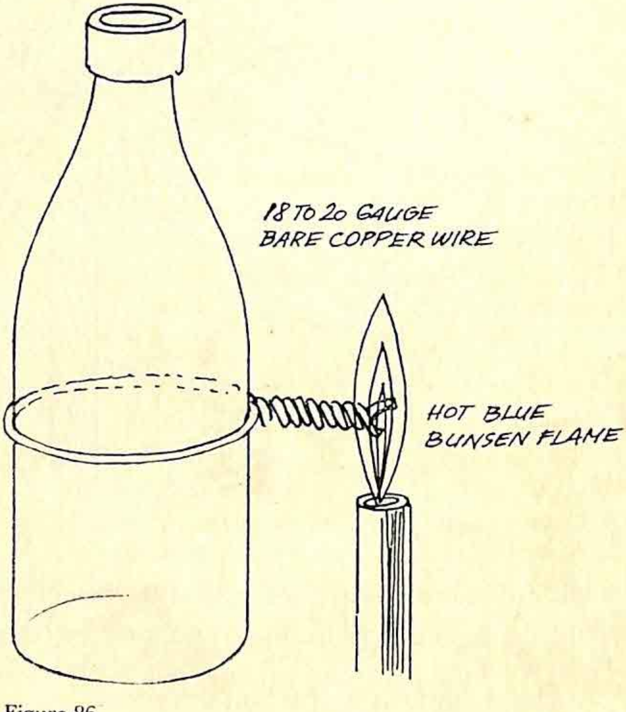


Figure 86

Glass Tubing

Most of the glass tubing with which the science teacher works is called soda glass.

The approximate composition is:

SiO_2	70-75 per cent.	Na_2O	10-20 per cent.
K_2O	0- 5 ,, ,,	CaO	5-15 ,, ,,
	Al and Fe oxide	1-5 per cent.	

It is a cheap glass and can easily be softened in the ordinary bunsen burner flame.
Always use new glass tubing. Glass kept for a long time devitrifies. Devitrification is the name given to the processes when the outside of glass exposed to air looses alkali, leaving an excess of silica, which crystallizes. Such glass hardly ever works satisfactorily.
It is best to order glass tubing in small quantities, which will be used fairly quickly.

Storage

Glass tubing is usually supplied in 5-feet lengths, which means that it is unwieldy and presents storage difficulties. Glass tubing can be stored *vertically or horizontally*, but in either case different sizes should be kept separate from each other. Whether tubing is stored vertically or horizontally is a matter of preference or of available space.

Vertical storage

There are many devices for vertical storage, the simplest being to stand the tubing in a number of boxes (one box to each size), and let the tubing lean against the wall.
Another way is to construct a wooden framework above the box so that each size has its own compartment.
The latter means of storage has a lot against it. It looks untidy, the glass ends on the floor and becomes cracked and broken, short lengths fall into the box and are lost and broken and objects knock against the tubing breaking it.

Horizontal storage

Using battens and plywood, construct a nest of racks about 5 feet high, 1 foot 6 inches wide, and 5 feet 6 inches long (as shown).

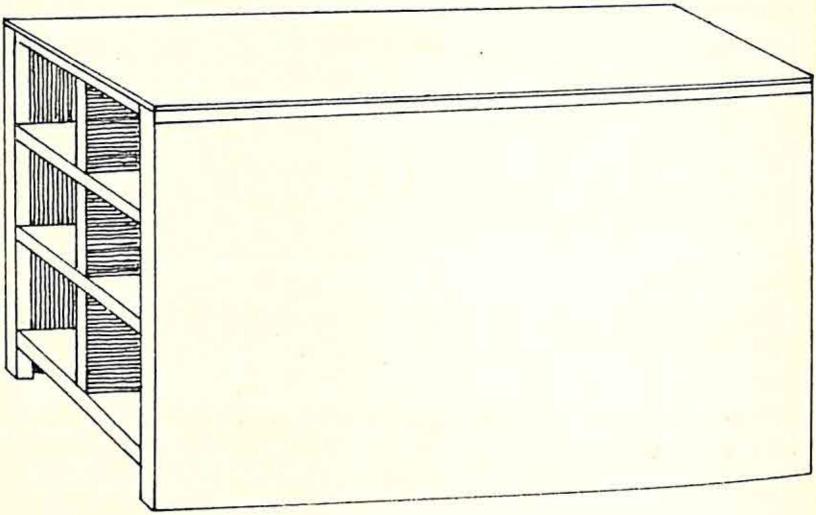


Figure 87

The ends of the glass protrude slightly from the nests and can be selected easily. Each 'nest' contains its own size of tubing.

Conditions for Glass-working

1. *Temperature*

A temperature of about 70° F. is usually found suitable. In warmer climates a higher working temperature is possible. In cold climates there are cooling problems.
The most important factor is an area free from draughts. Draughts cause premature cooling in parts of the heated glass and this leads to fractures.

2. *The bench*

This must be covered with a sheet of asbestos. The bench must be of such a height that, with an appropriate-sized stool provided, the worker can sit comfortably, easily resting his feet on the floor and his elbows on the bench.

3. *Lighting*

The flame used should be almost non-luminous. In bright sunlight this cannot be seen and therefore burns may result. The

lighting should be subdued so that the flame and the colour of the glass in the flame can be seen.

4. *Waste box*

In normal working conditions much broken glass is produced. A large biscuit tin serves well for disposal of broken pieces. Great care must be taken in clearing glass off benches. This is best done by using a small brush and sweeping the pieces directly into the tin.

5. *Eyes* should be protected with goggles or an eye-shield.

6. *Tools*

(*a*) A *batswing* or fishtail flame is essential. This is a long flat flame and is made by buying a special burner or slipping a fitting over a bunsen burner.

The wide flame means that 2 inches to 3 inches of glass tubing can be heated at the same time: in this way it is possible to make good curves in the glass tubing.

(*b*) *Air or oxygen blowpipe*

This is a burner which mixes a blast of air from foot bellows (or oxygen from a cylinder) with gas, to give a very hot flame. The amount of air or oxygen and gas can be very carefully controlled. Reference should be made to suppliers' catalogues before buying, and the types of gas being used should be mentioned when ordering.

(*c*) Glass-cutting knife.

(*d*) A number of triangular files.

(*e*) *A blowing tube*

This is a length of rubber tubing fitted with a glass mouthpiece. This is fitted to the work being blown.

(*f*) *End-seals*

Often there is an open end in an article to be blown. This must be sealed and a number of end-seals can be made as shown in Figure 88.

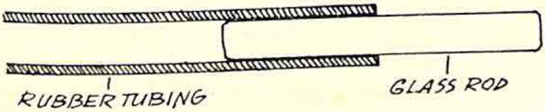


Figure 88

Cutting glass tubing

Figures 89, 90 and 91 show the stages in cutting a glass tube.

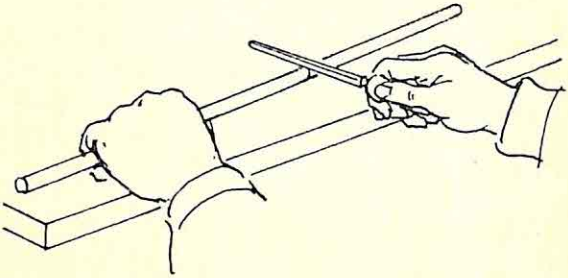


Figure 89

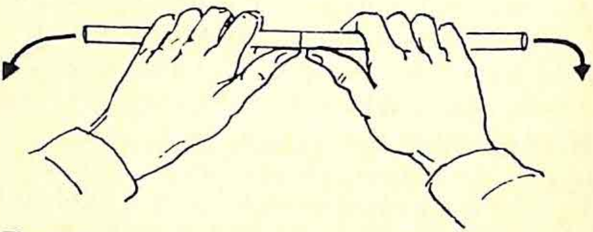


Figure 90

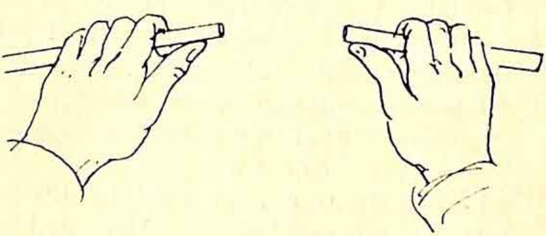


Figure 91

Fire polishing

All glass tubing has very sharp ends, which can be dangerous. They can be made smooth by a process called 'fire polishing'. The ends of the tubes are held in a burner flame and the tube turned constantly until the ends have softened. All sharp edges will have gone. Be careful not to heat too long or the end of the tube will melt and seal up (see Figure 92).

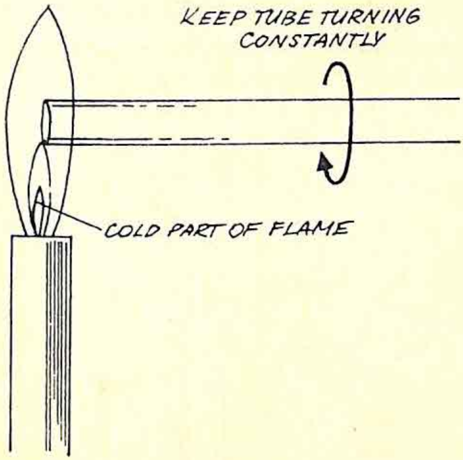


Figure 92

Bending glass tubing

Hold the tubing horizontally in the fishtail as shown in Figure 93.

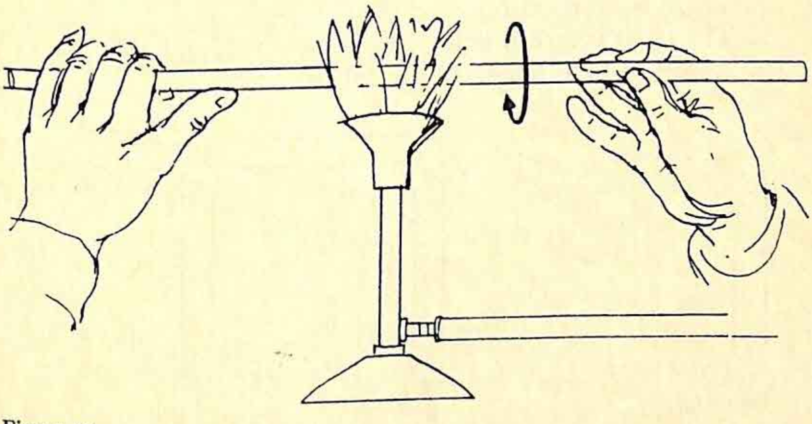


Figure 93

Ensure that the tube is rotated continuously to give an even heating. As the tube gets hot it will become pliable and it should be removed from the flame and bent to the required shape. The tube is pliable if it bends under its own weight.
NOTE: If a fishtail or batswing burner is not available, hold the

tube at an angle in an ordinary bunsen flame. This should give even heating over the necessary length of tubing (see Figure 94).

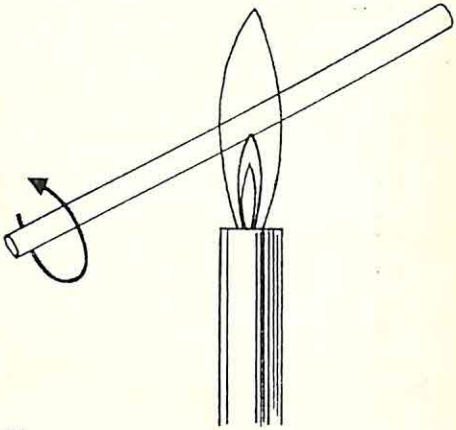


Figure 94

If the instructions are followed carefully a smooth, strong bend should result. A poor bend will result if:

1. There is overheating.
2. The bend is forced before the glass is really pliable.
3. An insufficient length of the tube is heated.

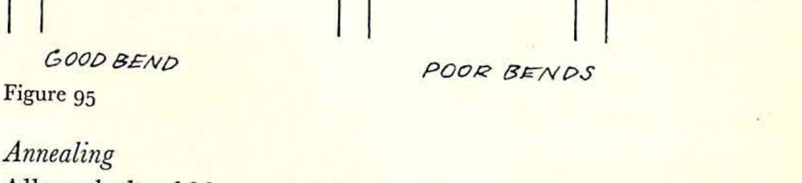


Figure 95

Annealing

All work should be cooled slowly. This is known as annealing. Close the airhole on the burner, giving a luminous yellow flame, and hold the bend in the flame, moving it slowly in and out of the flame. A layer of soot may form on the bend. This is a good thing and can be wiped off later. It is a good idea to mark the

shapes of bends on the asbestos sheet on the bench, for easy reference.

A science teacher gradually gets to know the most useful bends, but the ones shown in Figure 96 are the most common. (The angles given are approximate.)

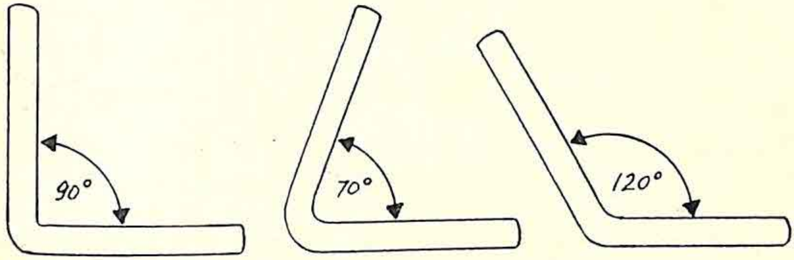


Figure 96

Bulb blowing

Blowing bulbs is the next step in glass-working. Follow the steps below:

1. Seal the end of the glass tube.
2. Continue heating and rotating the end in the flame when the end and walls near the end, begin to thicken.

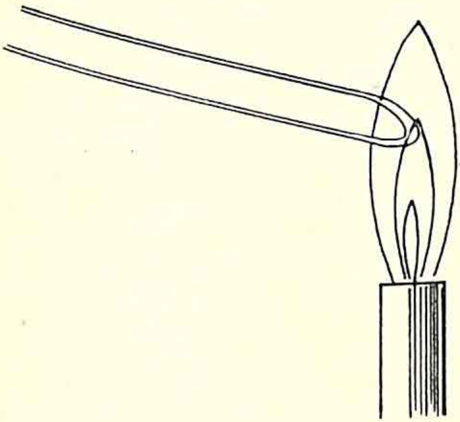


Figure 97

3. Remove from the flame and hang the bulb vertically downwards. Give a gentle blow until a small bulb appears.

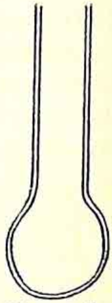


Figure 98

4. Place the bulb back in the flame, rotating it steadily until the bulb and a short length of the walls above the bulb collapse a little.
5. Remove from the flame, hang vertically downwards and blow the bulb to the size required.

To blow a bulb in the middle of a tube

1. Seal up one end in the flame.
2. Heat the section where the bulb is required, *pushing* the ends in. (This thickens the glass to make the bulb.)

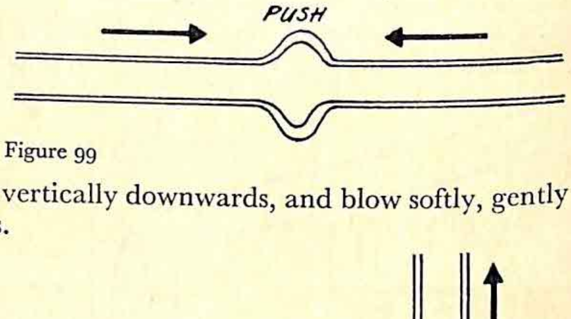


Figure 99

3. Hang the tube vertically downwards, and blow softly, gently *pulling* the ends.

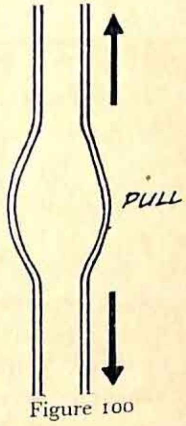


Figure 100

4. Repeat these two processes until a bulb of the required size is obtained.
5. Anneal (see above).

Joining glass tubing

1. Seal the end of a tube.
2. Continue heating, then remove from the flame and blow hard, giving a large, brittle bulb.

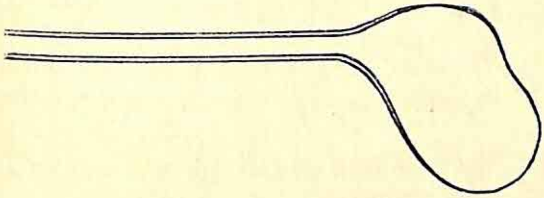


Figure 101

3. Break the bulb with a file, leaving the tube slightly opened.

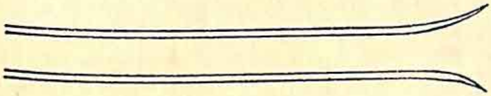


Figure 102

4. Place two such tubes together in the flame and as the glass melts they will join.

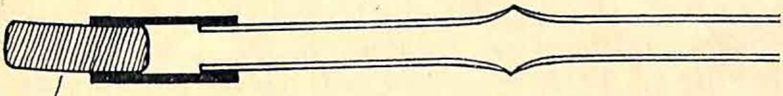


Figure 103

5. Let the glass thicken and blow gently, giving a small bulb.

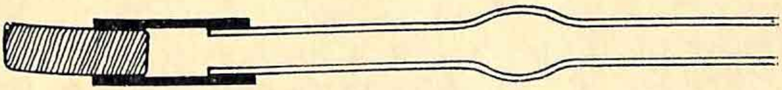


Figure 104

6. Continue heating and rotating. The bulb will thicken. Then *pull out gently until a straight tube is obtained.*
7. Anneal and then test the joint.

The bends, bulbs and joins described are the beginnings of glass-working. They are not easy to do and require much practice.

If any attempt is to be made on more advanced glass-work, reference should be made to textbooks on glass-working.

6 MODELS, DUPLICATORS AND DISPLAY APPARATUS

Papier Mâché

This can be used for making models.

1. Cut old newspapers and other papers into strips 2 to 3 inches long and leave them soaking for about a week in a thin paste of flour and water. The pulp may then be moulded like clay.
2. Mould the pulp to shape and let it dry for a day or two. Now give it two or three coats of shellac.
3. Now layer narrow strips of newspaper, soaked in the flour and water paste for several minutes. In this way, build up several layers.
4. Allow to dry and then sandpaper with a fine grade of paper. Now apply several coats of shellac, allowing each coat to dry before applying the next. The model is now ready for painting.

A great many biological models can be made in this way and papier mâché is also useful for models in the physical sciences.

Plaster of Paris

Plaster of Paris sets quickly in the shape of the mould or article on which it is placed. Plaster casts can be made of hands, feet, bones, leaves, etc.

Coat whatever you are casting with a layer of petroleum jelly.

Use a clean tin (which can be discarded later) and a stick.

Pour enough water in the container to fill the mould (this must be estimated first). Sift the Plaster of Paris into the water in the container, allowing it to sink to the bottom. When no more plaster will sink to the bottom, add a little more and stir it until it has the consistency of thick cream. Now pour it into the mould or on to the article.

After the plaster has cooled and set let it dry for a day.

The plaster can now be painted with water colours and finished with a coat of shellac.

Some points to remember are:

Plaster of Paris sets quickly. If you wish to have an even quicker set add *salt*. To delay setting add *vinegar*. Sandpaper the cast and trim off surplus plaster with a knife. *Do not throw plaster*

down the sink as it sets hard and blocks it.

Plaster of Paris gives a negative cast. To get a positive cast first make a negative one. Now coat with petroleum jelly and make a positive cast. Break off and destroy the negative cast to get the positive one.

Plasticine

Plasticine or moulding clay is very useful to have around the laboratory. It can be obtained from most toy shops and comes in many colours.

A Cheap Duplicator

Any tin dish at least 9 inches wide and 14 inches long will make a gelatine duplicator that will take foolscap paper. The gelatine slab is made in this way:

1. Dissolve 1 ounce of clear gelatine in 4 ounces, by weight, of water and leave for one hour in a cool place.
   NOTE: The addition of a little disinfectant to the water will prevent moulds from forming.
2. To this add 6½ ounces of glycerin. Mix slowly for several hours over a salt-water bath.
3. Pour the mixture into the dish and allow to harden.

After some use the surface of the gelatin may be damaged. Simply melt again over a water bath and pour back into the dish.

Using the duplicator

1. Make a master copy by writing or typing on smooth, hard paper.
   NOTE: A special carbon paper is used for making this copy. The carbon goes under a number of different names, one of which is *ditto sheets*. These cost between sixpence and a shilling each, but one carbon paper can be used a number of times if written on carefully.
   It will be found easiest if you place the *ditto sheet* between two pieces of paper. Write on the top piece and the carbon copy will appear on the one beneath.
2. Wet the surface of the gelatin with a moist sponge. Blot the

excess water with a clean sheet of paper (*not* blotting paper).

3. Apply the master copy, face downwards, on the gelatin, press it evenly down and leave it for one minute.
4. Press gently all round again and remove. The tray is now ready to produce 50 to 75 copies.
5. When all the copies are obtained, wash the ink off the tray straight away with a clean, wet sponge. The tray is now ready for use again. Use very warm water.

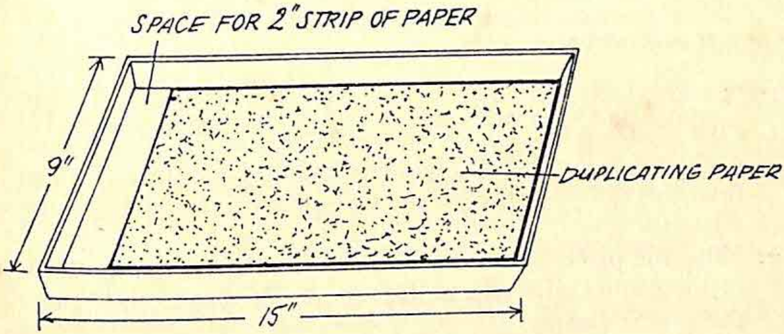


Figure 105

6. To prevent the gelatin surface from being scratched by finger nails when you lift off the papers, place a 2-inch strip of paper across one end (shown in Figure 105).

Ordinary duplicating paper gives perfectly good results.

Charts

Hanging charts on walls

Charts are best hung from a wooden strip fixed to the wall. The wooden strip should be $2\frac{1}{2}$ to 3 inches wide and 1 inch thick. It should be at least 6 inches longer than any chart you wish to hang.

These wooden strips should be fitted in different places in the laboratory.

The strips are fixed by two screws $2\frac{1}{2}$ to 3 inches long, driven into plugged holes in the wall (see Figure 106).

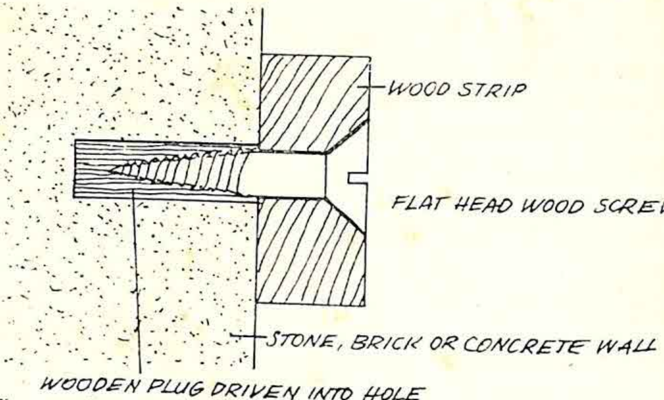


Figure 106

Fixing instructions

1. First drill two holes in the wooden strip about 6 inches from each end of the wood. The holes should be wide enough to take the shank of the screw. Countersink the holes at the same time.
2. Hold the piece of wood in position and mark the position of the screws with a pencil. Remove the wood and pencil the marks clearly.
3. Make the hole in the wall with a *rawldrill*, available at all hardware stores. No. 10 size is most convenient though sets of drills may be bought. Use a medium-weight hammer. Twist the rawldrill through the layer of plaster or cement at the two marks.
4. Hold the drill and hammer as shown in the Figure. Give a few light taps first.

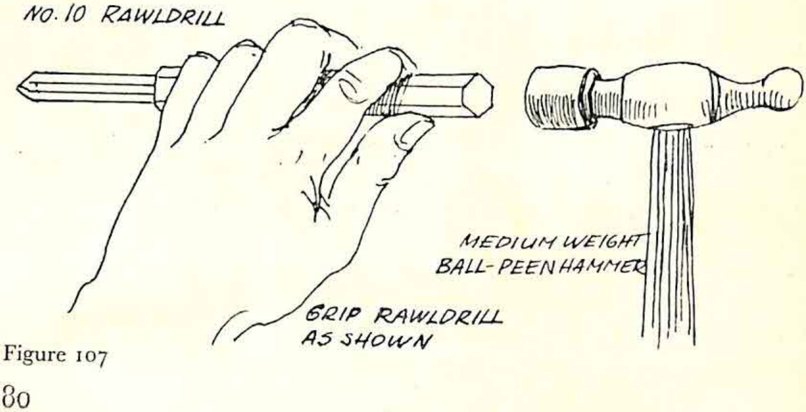


Figure 107

5. Now tap firmly, giving the rawldrill a twist between each blow so that a round hole is produced and the drill does not jam in the masonry. Increase the strength of the blows as necessary.
6. Drill the hole $\frac{1}{4}$ inch longer than the threaded portion of the screw. Practice is necessary to do a really good job. (Test the length of the hole by inserting the screw.)
7. Rawlplugs can be bought, or some filling paste, but a simple and effective plug can be made from a piece of soft wood. Cut the wood slightly longer than the depth of the hole and taper it to enter. The wide end must be wider than the hole.
8. Hammer the plug in firmly and cut off the end with a knife or chisel.
9. Make a starting hole for the screw in each plug, with a bradawl.
10. Hold the strip to the wall, insert the screws into the starting holes and drive them home with a screwdriver.

You can mount the charts with drawing pins or fasten anything on with nails, screws or cup hooks.

If all charts are fixed to a thin wooden strip (a piece of dowel rod will serve), charts can be hung on cup hooks as shown in Figure 108.

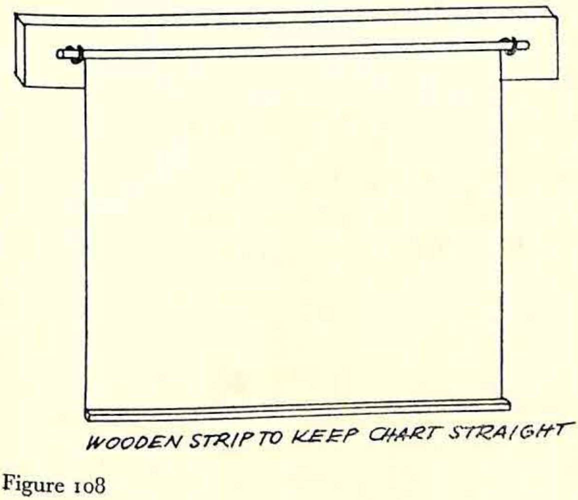


Figure 108

Storing charts

If charts are fitted with the thin strip of wood they can be stored flat very conveniently on two brackets fixed to the wall as shown in Figure 109.

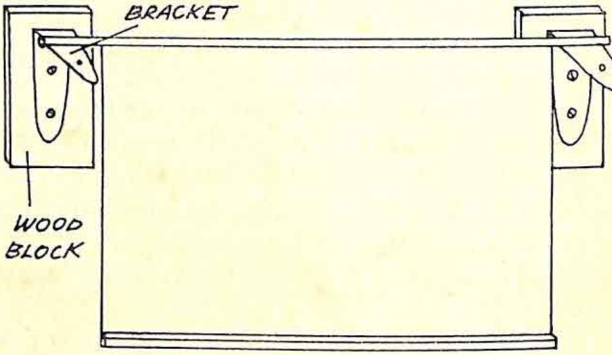


Figure 109

These brackets are fixed by screws to wooden strips previously fixed to the wall in the same way as just described.

Demonstration board for felt or flannel cut-outs

It is convenient to use a self-standing board, using the back area as a storage place for the flannel or felt cut-outs.

The board itself should be made of 'soft board', which is sometimes called 'ceiling board' or goes under a trade name. This can be purchased at most builders' merchants or hardware stores.

The measurements of the board and the framework to which it is fixed are not critical; build it to suit your particular needs.

Cut the side boards from a piece of timber 18 inches by 10 inches by 1 inch cut as in Figure 110.

Cut the board to fit the frame and fix it by $1\frac{1}{2}$ inch long clout nails. The nail heads should be punched below the surface and the holes filled with putty.

Paint the board with blackboard paint and fix a carrying handle as shown.

The bottom should be made from $\frac{1}{4}$-inch or $\frac{1}{2}$-inch plywood.

Cut and fit it after the frame has been made.
Felt or flannel cut-outs will adhere to the board.

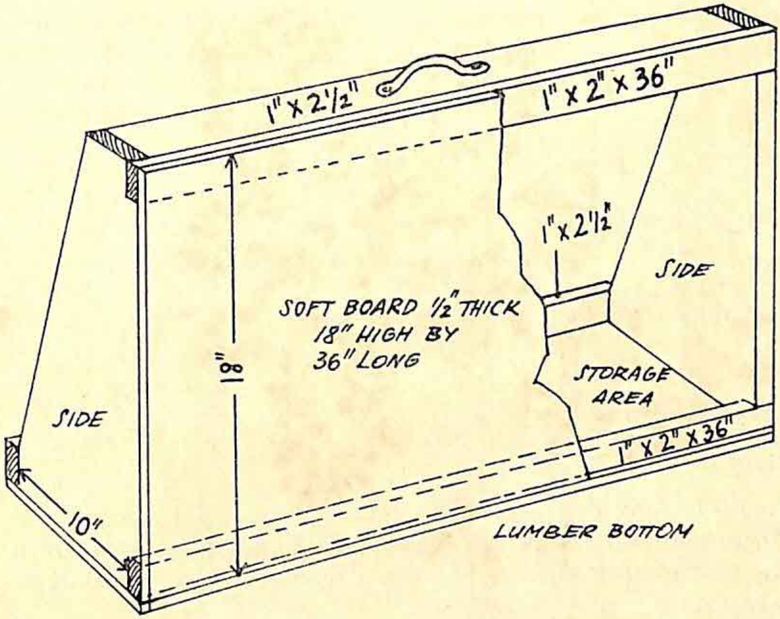


Figure 110

7 ELECTRICITY

Electrical Wiring: making connections

The insulation must be removed before any connections can be made. It can be removed with a knife, a pair of side-cutting pliers or a special 'wire stripper'.

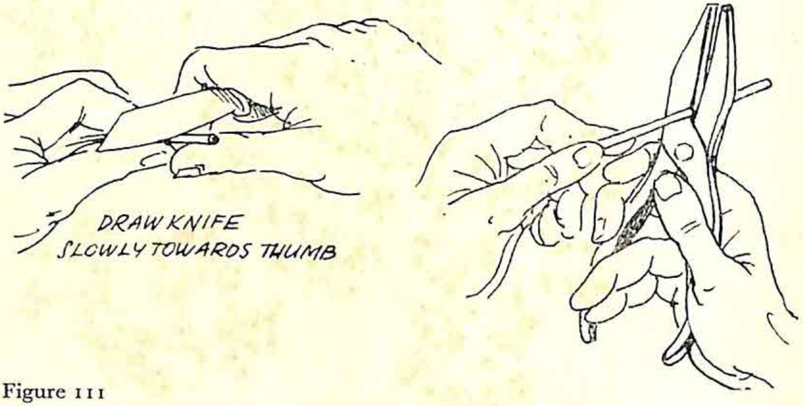


Figure 111

Avoid nicking the wire or it will easily break.
All insulation must be removed. Special care must be taken in the case of some enamelled wire. The enamel coat must all be scraped off.
The bare end of wire should be scraped away to make a proper contact. About $\frac{3}{4}$ inch of insulation should be removed, to make a proper loop to fit round a terminal screw.

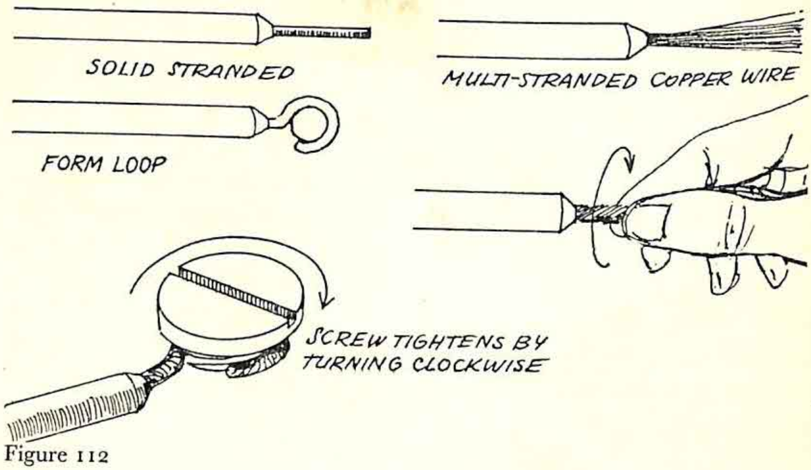


Figure 112

Single strand wire should simply be looped and screwed so that each turn of the screw tends to tighten the loop. The round shaft of a screwdriver can be used to form the hook or loop.
Multi-strand wire must have the strands twisted together as shown in the diagram.

Wiring a three-pin plug

This is shown in Figure 113. The *Earth* pin is usually the largest of the three pins.

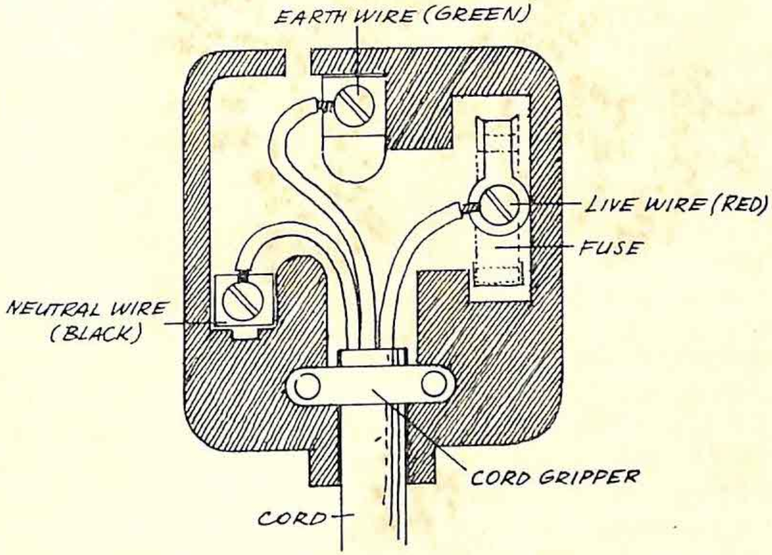


Figure 113·

E. The *Earth* wire (*green*) runs through the centre of the plug for connection to the Earth pin (often marked with the letter E).
L. The *Live* wire (*red*) is connected to the right-hand pin (often marked with the letter L). *Fuse* (held in position with the fuse clips—one on each end).
N. The *Neutral* wire (*black*) is connected to the left-hand pin (often marked with the letter N).

SAFETY RULE: In no circumstances should the *Earth wire* (*green*) be connected to either of the other two terminals. All machines containing motors should be 'GROUNDED' by using a three-pin plug.

Wiring a socket

The underwriter's knot prevents strain on the connections. All sockets that have a metal exterior must have an insulating fibre shell.

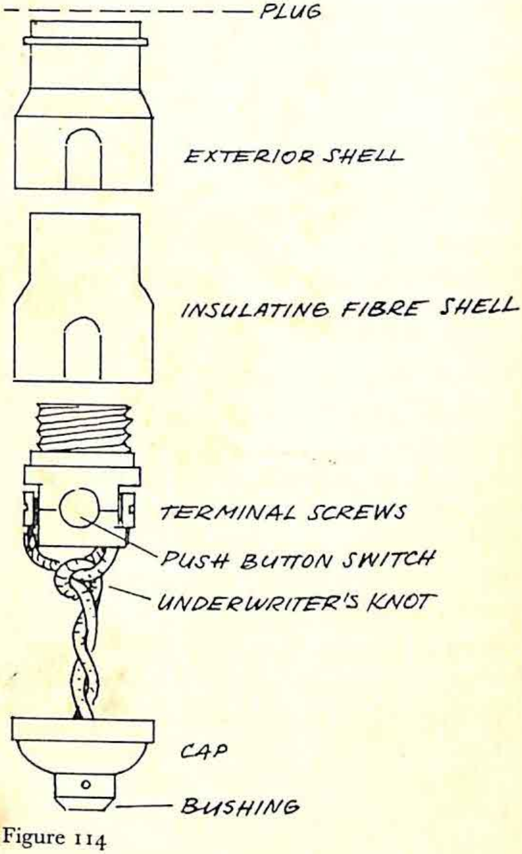


Figure 114

Fuses

Renewing a fuse

Before attempting to renew a fuse in a house or a school building the electric current MUST BE SWITCHED OFF.

If possible this should be done where the mains enter the building. This will render the whole building 'dead' so that all circuits and fuses can be touched safely.

Where it is impossible to switch off at the mains, then a switch

will usually be found on a small switchboard, which distributes electricity to the particular part of the building concerned.

Older buildings

In older buildings the fuse box is often fitted with a simple catch. Close beside this is a large switch marked *ON/OFF* close to the handle. In some cases there will be more than one switch. Switch off all the switches on the board. You can now safely open the fuse box.

Newer buildings

As a safety device, all new wiring has the fuse box and switch combined in such a way that the fuse box cannot be opened unless the switch is in the *OFF* position.

Fuses

A fuse is a length of soft wire with a low melting-point. If the quantity of current in the circuit gets too high the wiring becomes hot and dangerous. But before this stage is reached the fuse wire melts and the circuit is broken.
Modern fuses have the wire encased in a cartridge. If the fuse blows, all that is necessary is to remove the old cartridge and insert a new one.
Cartridges come in different shapes and sizes. It is a good idea to examine the fuse box and order a supply of spare cartridges of the type fitted. All these cartridges fit into spring slots.

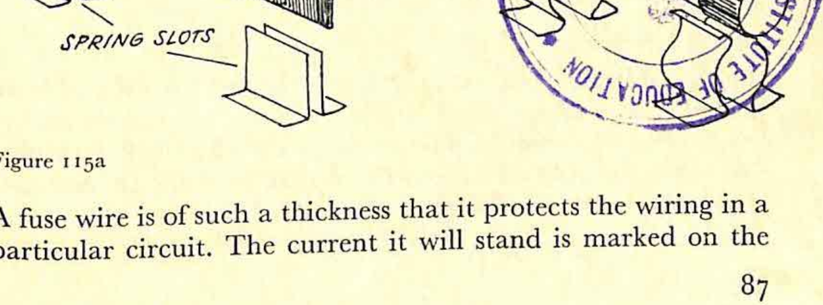


Figure 115a

A fuse wire is of such a thickness that it protects the wiring in a particular circuit. The current it will stand is marked on the

cartridge. *The correct fuse should be fitted.* Usually there is a guide in the box to show the fuses to be fitted: if this is not shown the safe thing to do is to fit the same size fuse as the one you have removed. Fuses are usually marked 2 amp., 5 amp., 10 amp., 13 amp. and 15 amp.

Older fuses simply use fuse wire which has to be screwed into place. The fuse holder is made of porcelain. The wire goes from screw A to screw B across a slit in the porcelain block. Fuse wire

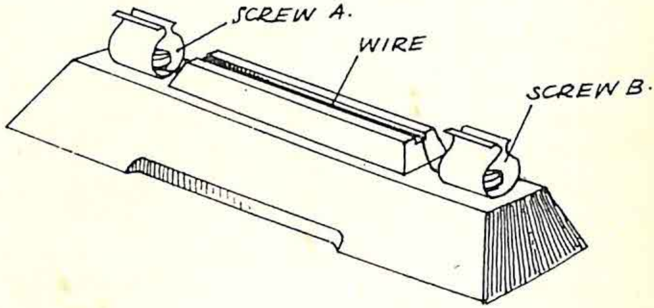


Figure 115b

is bought in different thicknesses. The current rating is shown on the card of wire. The usual wire is 5 amp., 10 amp. and 15 amp.

Changing electric light bulbs and plugs

It is a safe and sensible precaution to switch off before changing any light bulb or socket.

Some modern power plugs carry a fuse inside the plug. Usually the plastic cover has the word *FUSED* on it. The most common plug of this type is the *square-pin* 13-amp. plug shown in Figure 116.

The cartridge fuse fits inside the casing.

Fusing experiments

Electrical instruments can very easily be overloaded and burnt out. To safeguard against this a teacher should insist that all circuits set up by the pupils are checked by him before the final connection is made or the switch pressed. Even then overloading can occur and it is a safe plan to insert a fuse between the source of electric supply and the apparatus.

If mains electricity (200-250 volts or even 110 volts) is being used, the fuse should be enclosed. For low-voltage work (24 volts

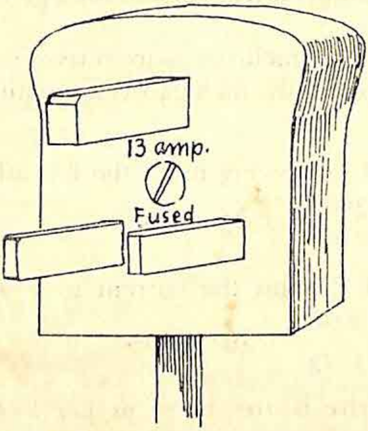


Figure 116

downwards) a simple fuse, which is open, can be used. This can be made easily by connecting a length of appropriate fuse wire across two terminals in the circuit.

Some Useful Information

Resistance wire

Resistance wire is sold under a number of trade names such as *constantan*, *eureka*, *nichrome*, etc. Companies that manufacture resistance wire usually note the resistance of the wire per foot or per metre on the spool. They also often furnish an information sheet or handbook.

Below is a table of resistance for nichrome wire containing

Wire gauge	Resistance per foot (ohms)
No. 20	0·645
,, 22	1·030
,, 24	1·650
,, 26	2·649
,, 28	4·328
,, 30	6·529
,, 32	10·313
,, 34	16·575
,, 36	26·400

75 per cent. nickel, 12 per cent. iron, 11 per cent. chromium and 2 per cent. manganese.

Calculations of the length of resistance wire required for a given purpose can easily be made.

For example: what length of No. 32 michrome wire is required to make a 300-watt soldering-iron for use on a 240-volt circuit? This is found in these stages:

Stage 1 Find current which will be flowing using the formula $I = \frac{W}{E}$. Therefore $I = \frac{300}{240} = 1{\cdot}25$ amps.

Stage 2 The resistance required to limit the current to 1·25 amps is $R = \frac{E}{I} = \frac{240}{1{\cdot}25} = 192$ ohms.

Stage 3 The resistance of the wire is 10·313 ohms per foot. Therefore No. of feet $= \frac{192}{10{\cdot}313}$ feet $= 18{\cdot}64$ feet (18 ft. 7 in.), i.e. 18 feet 7 inches of wire will be required.

Sometimes pupils find difficulty in making calculations on resistance, current, voltage and wattage. The circle device shown below may be of help to them. A finger placed over the item to be found shows whether the remaining two items are multiplied or divided, and in which way.

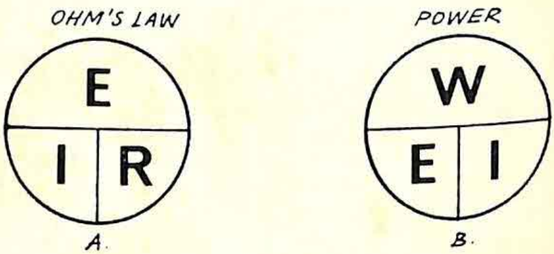


Figure 117

For example, in (A) if R is required, it is obtained by dividing E by I. In (B) if W is required it is obtained by multiplying

Resistance of Copper Wire

Gauge *B & S*	Diameter In Decimals of an inch.	Ohms Per 1,000 ft Feet (25° C.)	Ohms Per Pound	Feet Per Pound	Feet Per Ohm	Nearest British *S.W.G.* No.
18	0·040303	6·36	1·29	203·374	157·35	19
19	0·03589	8·25	2·11	256·468	124·777	20
20	0·031961	10·12	3·27	323·399	98·9533	21
21	0·028462	12·76	5·20	407·815	78·473	22
22	0·025347	16·25	8·35	514·193	62·236	23
23	0·022571	20·30	13·3	648·452	49·3504	24
24	0·0201	25·60	20·9	817·688	39·1365	25
25	0·0179	32·2	38·2	1031·038	31·0381	26
26	0·01594	40·7	52·9	1300·180	24·6131	27
27	0·014195	51·3	84·2	1639·49	19·5191	29
28	0·012641	64·8	134·0	2067·364	15·4793	30
29	0·011257	81·6	213·0	2606·959	12·2854	31
30	0·010025	103·0	338·0	3287·084	9·7355	33
31	0·008928	130·0	539·0	4414·49	7·72143	34
32	0·00795	164·0	856·0	5226·915	6·12243	36
33	0·00708	206·0	1357·0	6590·41	4·85575	37
34	0·006304	260·0	2166·0	8312·8	3·84966	38
35	0·005614	328·0	3521·0	10481·77	3·05305	38-39
36	0·005	414·0	5469·0	13214·16	2·4217	39-40
37	0·004453	523·0	8742·0	16659·97	1·92086	
38	0·003965	660·0	13772·0	21013·25	1·52292	
39	0·003531	832·0	21896·0	26496·237	1·20777	
40	0·003144	1049·0	34823·0	33420·63	0·97984	

E and I. (E being in volts, I in amps., R in ohms, and W in watts.)

Resistance of copper wire

The table above is a guide to resistance and weight of various thicknesses of copper wire. There are various gauges in common use and it is important to know which gauge is being used. The gauge and number should be shown on the spool. If there is any doubt, determine the diameter of the wire using a screw gauge and relate it to the table.

B & S refers to *Brown and Sharp Gauge.*

S.W.G. refers to *Standard Wire Gauge.*

Thus *B & S* 24 Gauge is the same as *S.W.G.* 25 Gauge. It is 0·0201 inches in diameter or 20 'thou', meaning 20 thousandths of an inch thick.

Simple calculations from the above table avoid hit-and-miss guesswork in winding electromagnets. For example, a small dry cell will give up to $\frac{1}{4}$ amp. for a couple of hours at a time.

We know that a $1\frac{1}{2}$-volt cell forces a current of $\frac{1}{4}$ amp. through

6 ohms of resistance ($R = \dfrac{E}{I} = \dfrac{1\cdot5}{0\cdot25} = 6$ ohms)

Thus we require: 942 feet of No. 18 *B & S* Gauge
or 372 feet of No. 22 *B & S* Gauge
or 90 feet of No. 28 *B & S* Gauge
or $14\frac{1}{2}$ feet of No. 36 *B & S* Gauge

Identification chart for torch and pilot bulbs

A great variety of torch and pilot bulbs are available and they differ in the shape of the glass globe and in the bases.

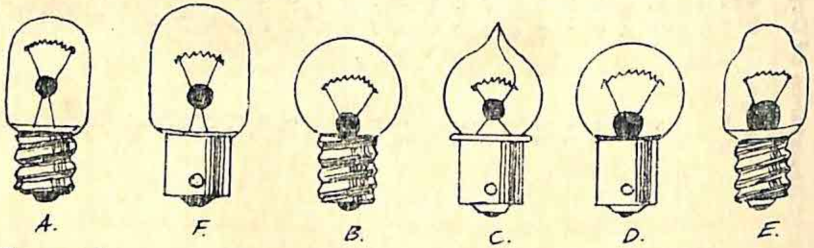


Figure 118

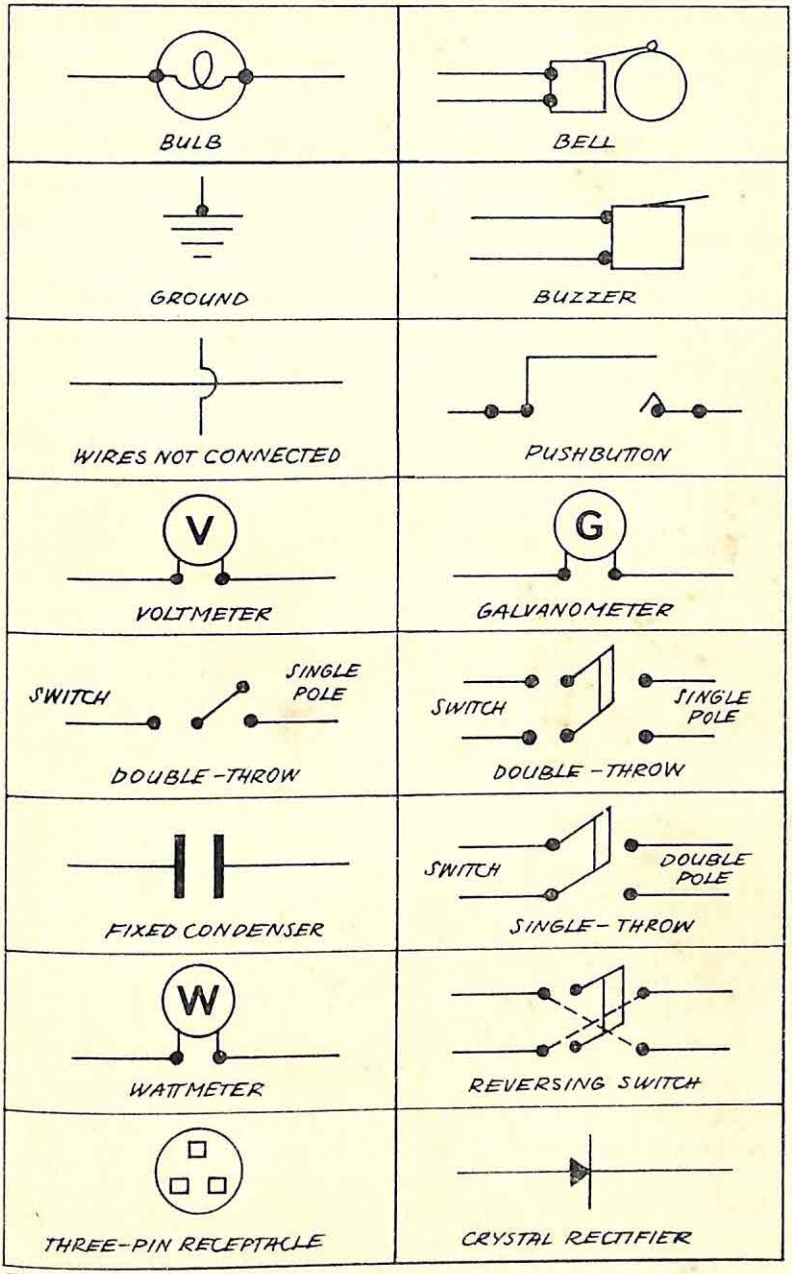


Figure 119a ELECTRICAL SYMBOLS

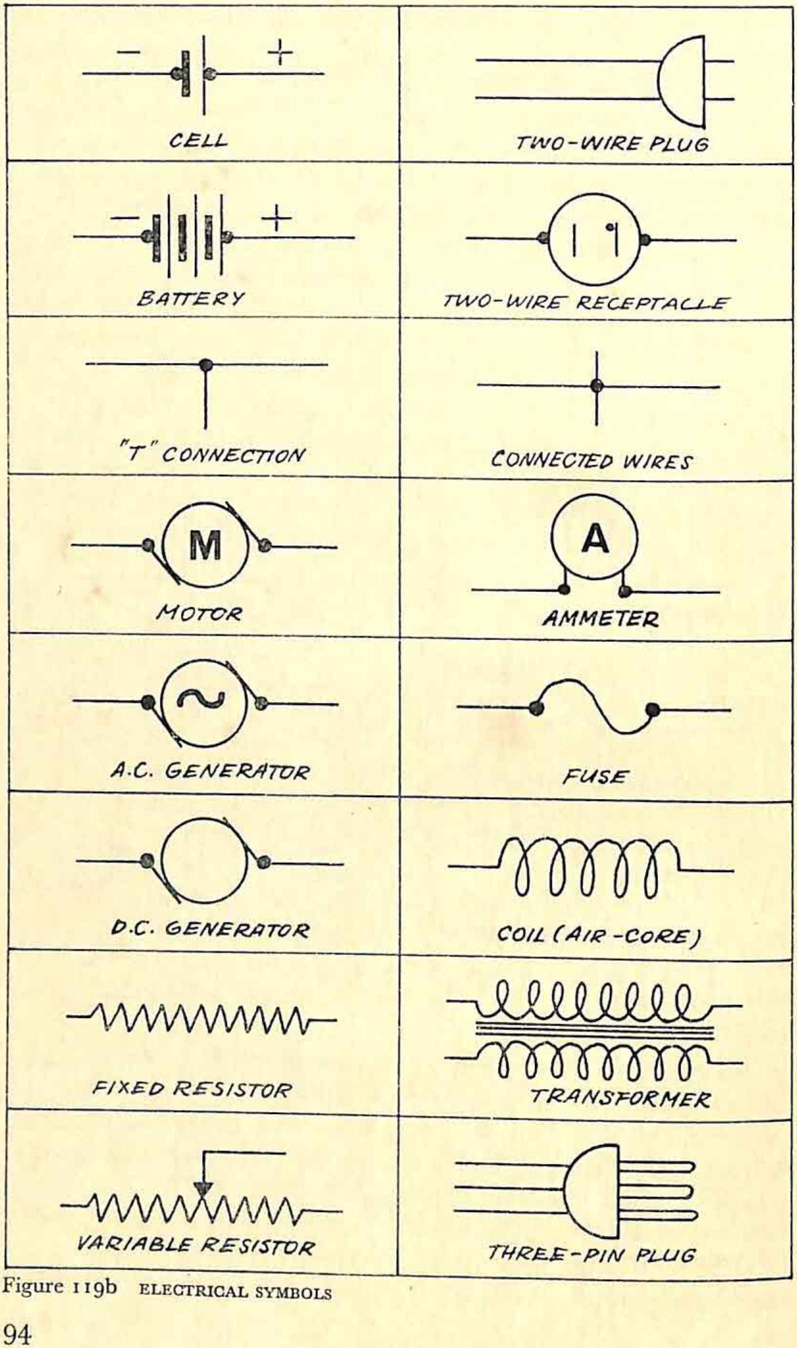


Figure 119b ELECTRICAL SYMBOLS

Sockets can be purchased to fit the various bulb bases. The most important information required is the voltage and current requirements of each bulb. In addition to the shape of glass and base, additional help in identification is the colour of the bead. The bead is the small bit of insulating material on which the filament is mounted. The colour of this bead supplies some information about the characteristics of the bulb.

Type No.	Base Style	Bead Colour	Voltage	Amperes
112	E	Pink	1·1	0·22
123	B	Pink	1·2	0·25
136	B	Pink	1·3	0·60
222	E	White	2·2	0·25
PR-8	C	White	1·9	0·60
PR-4	C	Purple	2·3	0·27
PR-6	C	Purple	2·5	0·30
40	A	Brown	6 to 8	0·15
41	A	White	2·5	0·50
42	A	Green	3·2	0·50
46	A	Blue	6 to 8	0·25
48	A	Pink	2·0	0·06
49	F	Pink	2·0	0·06
49A	F	White	2·1	0·12
50	B	White	6 to 8	0·20
51	D	White	6 to 8	0·20
292	A	White	2·9	0·17
292A	F	White	2·9	0·17

If two cells are connected in series, bulbs such as 222 and PR-4 may be used.

Cells in parallel give the same voltage as a single cell, but last twice as long.

In drawing up plans for electrical and radio circuits the symbols shown in Figures 119a and b are universally accepted. The actual objects are indicated by symbols instead of sketches. The same symbol always stands for the same object. This is illustrated in the following figure of an electric bell.

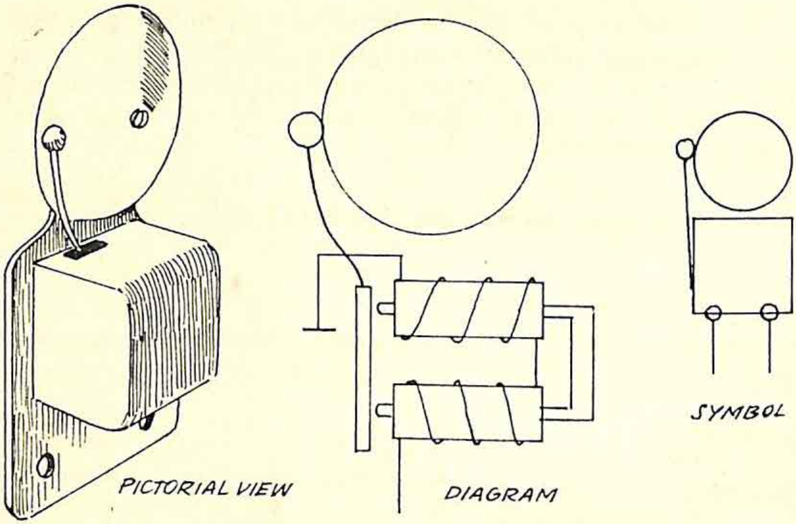
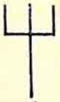
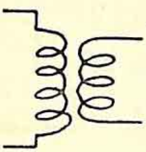
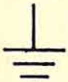


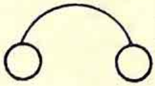
Figure 120

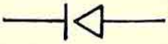
Symbols and Operations of Radio Parts


Antenna As radio waves speed past a conductor, an electric current is induced in the conductor. This current alternates in one direction at the same frequency as that in the transmitting antenna.

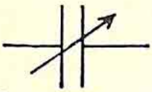

Antenna Coil The alternating current surging back and forth from the antenna through the primary of the antenna coil into the ground induces a similar flow of alternating current in the secondary of the coil.


Ground Transmitters cause a rapid surge of electrons from ground into the antenna and back into the ground. A similar feeble motion of electrons is induced by the radio wave in the receiving antenna.

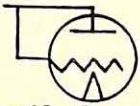

Phones The phones convert varying electric currents into sound waves which vary in time with the fluctuations of the current. By this means the varying current is converted to speech.



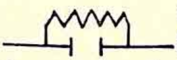
Crystal The radio frequency to which the tuned circuit is resonant is sent into the crystal to be rectified. The phones cannot respond to the high frequency of alternating current, but can respond to the audio component of the rectified wave.



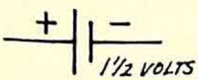
Tuning Condenser The tuning condenser, together with the secondary of the antenna coil, comprises the tuned circuit which selects from the many radio frequencies received, the single one to which it is tuned. By varying the capacity of the tuning condenser the responding frequency is changed, thus tuning to the desired station.



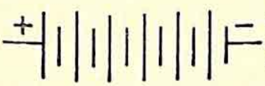
Diode Detection The fact that the current flows through the tube only when the filament is negative and the plate positive, causes the diode to rectify the radio frequency exactly as does the crystal.



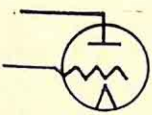
Grid Leak Radio frequency impressed on the grid flows through the grid leak condenser. The voltage drop across the grid leak resistance supplies the proper grid bias.



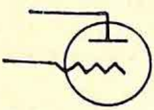
Battery 'A' The purpose of the 'A' battery is to supply the current to heat the filament to the temperature necessary to cause it to emit electrons.



Battery 'B' The 'B' battery maintains a positive charge on the plate and a negative charge on the filament and also supplies the additional energy necessary for amplification.

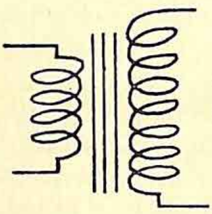


Detector Triode The grid and the filament of the triode detector act to rectify the incoming radio frequency. Variations on the grid are amplified in the plate circuit.



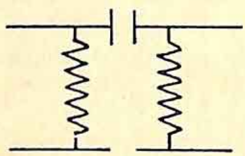
Audio Amplifier Triode Variations at audio frequency from the plate circuit of the preceding tube are impressed on the grid of the

amplifier and appear as greater variations in the plate current.

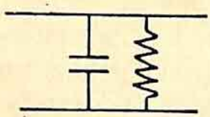


Transformer Coupling Variations in the primary (connected to the plate circuit of the preceding stage to induce greater voltage variations in the secondary) connected to the grid circuit of the succeeding tube. The transformer thus couples the two stages and provides a gain for amplification.

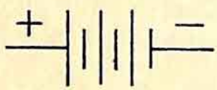
Resistance Coupling Voltage developed across the plate resistor R_1 feeds the varying signal to the grid of the succeeding tube.



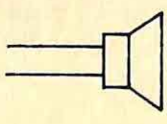
The coupling condenser is needed to keep the large positive voltage on the plate off the grid and at the same time it allows the signal to pass through. The grid leak resistor R_2 allows any charge accumulating on the grid to run off to the ground, thus preventing the effect of a floating grid.



Cathode Bias The voltage drop appearing across the cathode bias resistor is in such a direction that the grid is made negative with respect to the filament. This secures the necessary grid bias. The large condenser by-passes the audio frequency.



Battery 'C' The function of the 'C' battery is to supply the proper grid bias for the tube, approximately 4·5 volts.



Speaker The speaker converts varying electric currents into sound waves which vary in time with the fluctuations of the current. By this means varying current is converted to speech.

Opposite are some simple electronic layouts using the symbols mentioned above.

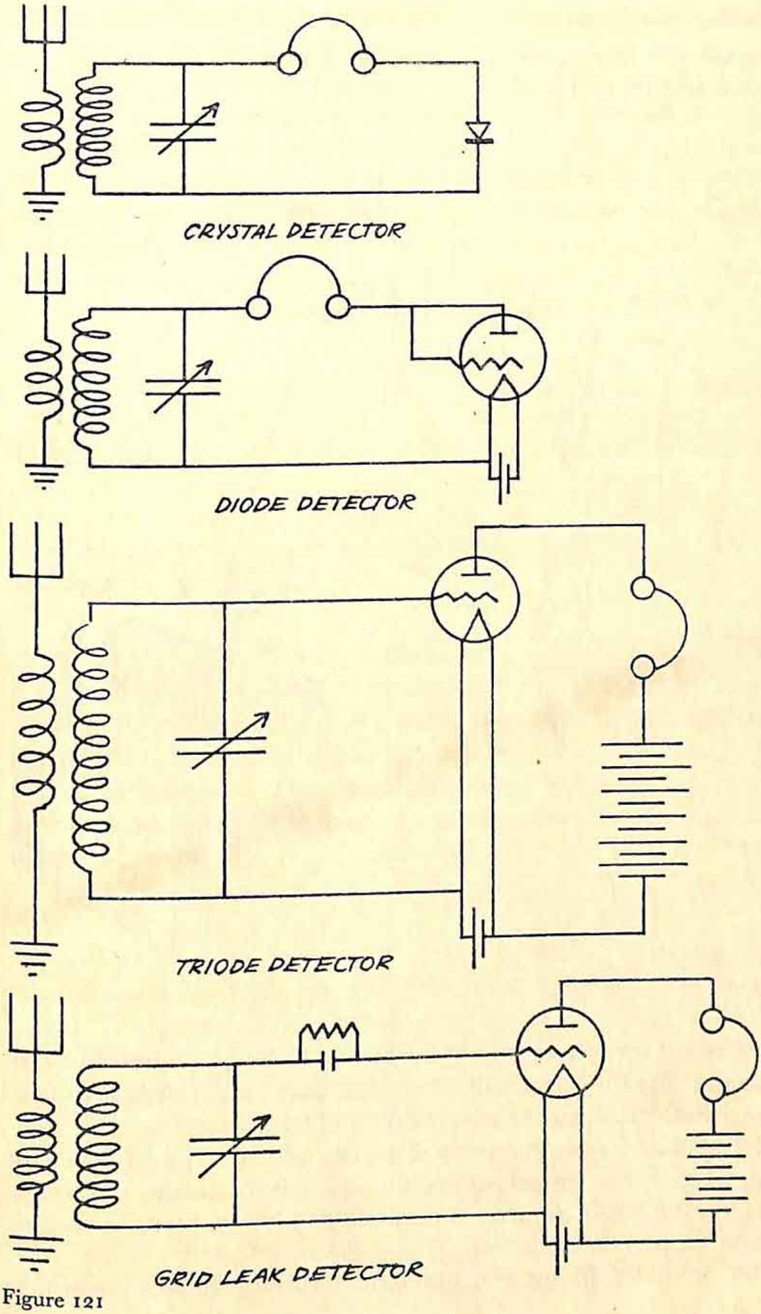

CRYSTAL DETECTOR
DIODE DETECTOR
TRIODE DETECTOR
GRID LEAK DETECTOR

Figure 121

Winding an electromagnet

A good job of coil winding can be done with the simple 'jig' shown in Figure 122.

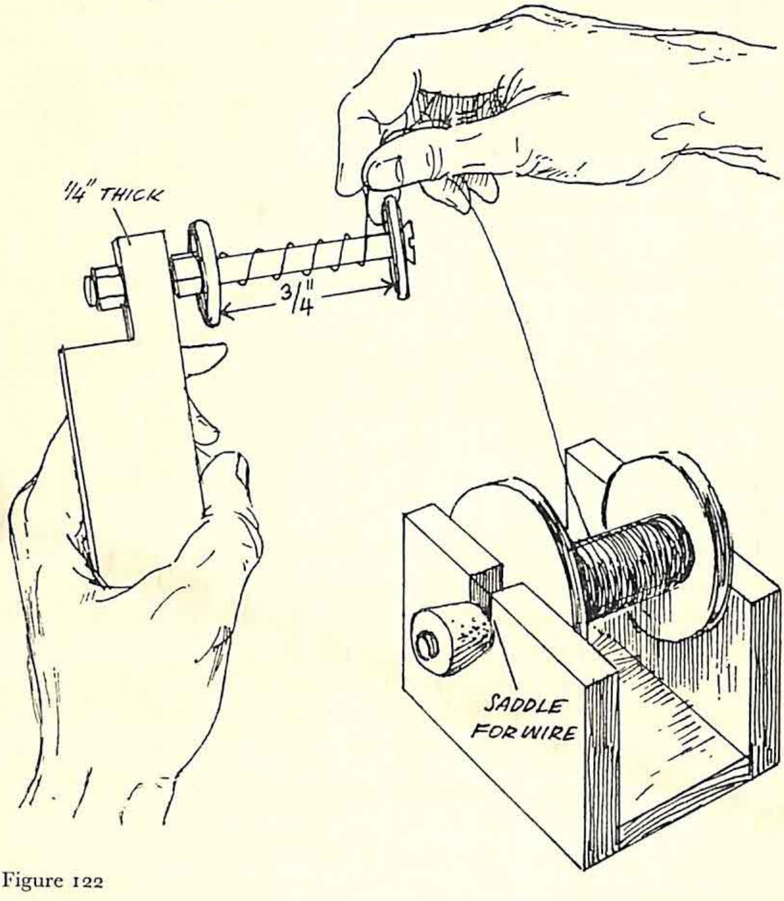


Figure 122

The wood used is $1\frac{1}{4}$ inches by $1\frac{1}{4}$ inches by $4\frac{1}{2}$ inches, but any size that fits the hand will serve. A $\frac{1}{4}$-inch hole is drilled to take the $\frac{1}{4}$-inch steel machine screw or bolt.

The spool of wire should roll freely and a saddle (shown in Figure 122) can be made very simply. It is made out of wood to fit the spool and the axle is made from glass rod with a cork or bung slipped on each end.

The detail of fixing the machine screw or bolt is shown in

Figure 123. The fibre washers can be purchased from hardware stores or alternatively, stiff cardboard rings can be cut. Washer A, which is slipped on the screw close to the wooden jig, has in it a small hole to allow for the wire to be passed through. Allow at least a 4-inch end of wire before winding. Hold the end of wire under the forefinger while winding as shown. A layer of tape will insulate the metal sinew and help keep the washers the correct distance apart.

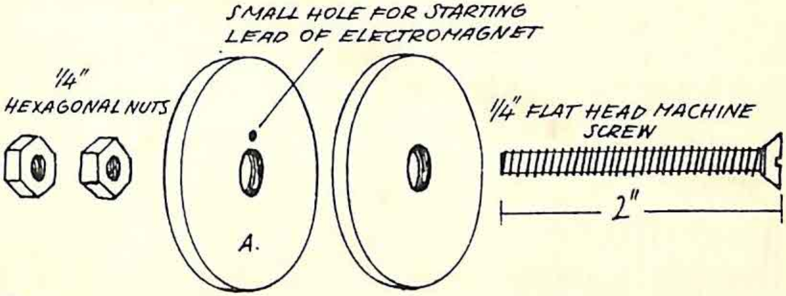


Figure 123

Wind 8 to 10 layers of No. 30 insulated wire (see information on length of wire and thickness given earlier). You should finish with the tail-end lead in the same place as the beginning lead. Again allow at least 4 inches of lead.

Bind the turnings with some layers of insulating tape or cellotape as well as tying the end-leads in position. Bare the ends

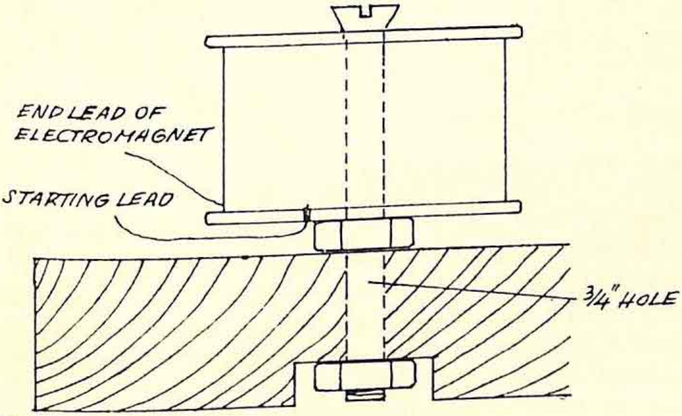


Figure 124

of the leads and test the winding. Connect the bare ends to a dry cell and try to pick up a few pins or rods.

The electromagnet can be mounted on a block of wood using the nuts used to hold it in the jig.

An alternative method of winding is to use a hand drill. Fasten the machine screw unit in the jaws of a hand drill that has been clamped in a vice. Tape the beginning lead to the chuck so that it will not interfere with the winding. Keep the wire taut with the left hand and the layers are wound evenly back and forth until the number of turns required is made.

Some practice may be required, but once the skill is mastered, coils can be wound very quickly.

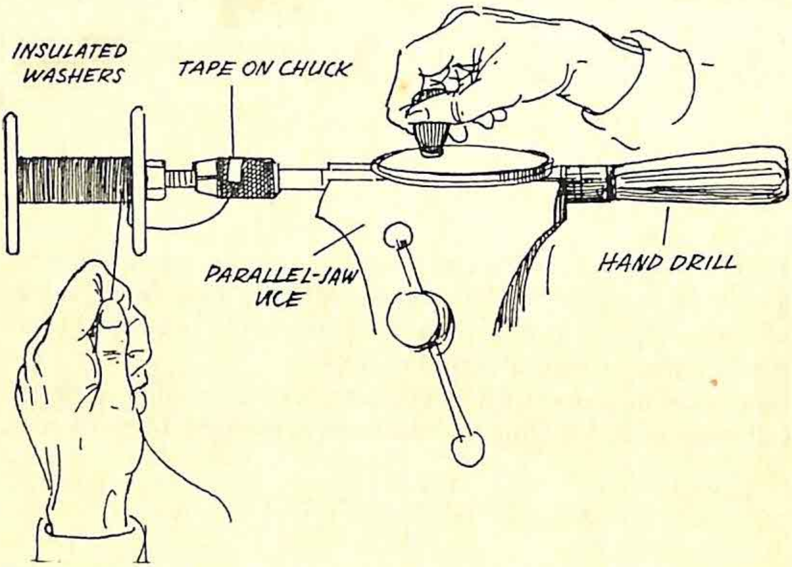


Figure 125

Some Pieces of Electrical Equipment

A simple electroscope

Figure 126 shows how this is constructed. The actual shape of the plastic box is immaterial. A clear plastic tumbler or drinking cup will serve, with a piece of sheet plastic for the top.

If required, a small copper, brass or aluminium disk can be soldered to the top of the machine screw.

It is sometimes better to use pure silk instead of cotton thread.

Instead of puffed rice, rice crispies may be used. There is also a substitute which works, if anything, better than these. Scratch out the pith from a dried maize stem, and roll it into two tiny balls. Thread these balls on to a length of silk thread and hang as shown.

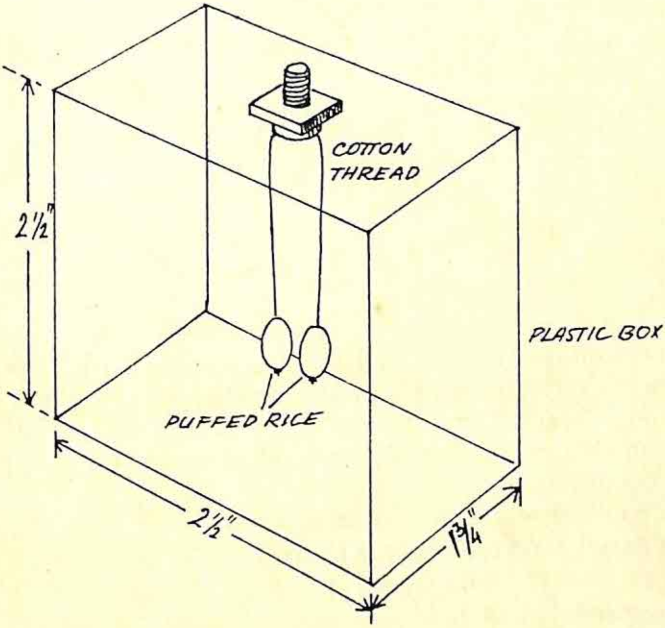


Figure 126

In humid climates some calcium chloride or silica gel placed in the plastic box is a help. Even then it is best to dry all electrostatic apparatus before use. Moist, humid conditions cause a quick decay of the charge.

Electrophorus

The charging base is simply an old, long-playing record screwed to a bench. It can be rubbed with fur.

The metal base is a disc of aluminium, which is soldered to the lid of an *Alka Seltzer* bottle. The bottle itself acts as the insulating handle.

Points to note

1. The lower surface of the disc must be slightly convex.

2. The edges of the disc *must* be smooth. In fact there should be no sharp edges on any electrostatic apparatus (except where it is required to show point discharge).

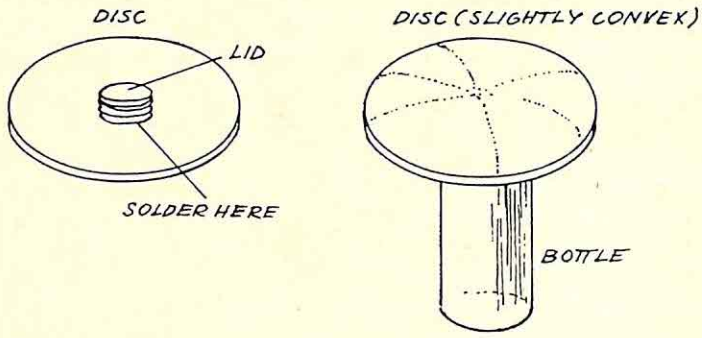


Figure 127

In humid conditions, ebonite and glass rods rubbed with silk and fur are not very successful in producing charge. New plastic materials give much better results. *Vinyl* and *acrylic* plastic rubbed with thin rubber 'dam' give abundant charges under the worst conditions.

Vinyl material takes on a *negative* charge.

Acrylic material takes on a *positive* charge.

A Galvanoscope

A galvanoscope can be made simply and cheaply and has a large number of uses. The figure shows how it is constructed. The wooden base is made of 1 inch thick material with a groove in the bottom cut *across the grain of the wood*, using a saw and a chisel. Two holes are drilled to take the terminals. A small magnetic compass about $1\frac{1}{2}$ inches to $1\frac{3}{4}$ inches in diameter, can be purchased from suppliers or can often be bought in a toy store for about two shillings.

The wire can be obtained from a discarded car motor or generator. Alternatively, any insulated copper wire from 18 gauge to 36 gauge can be used. The more turns of fine wire, the more sensitive is the galvanoscope. The beginning of the wire is attached to one terminal and the end to the other. Wind the turns over the compass and hold the wire in position with cellotape.

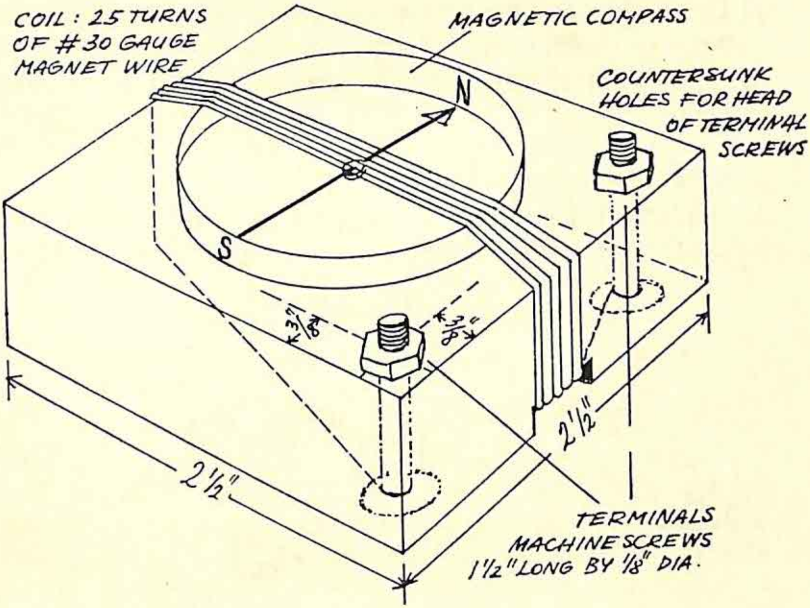


Figure 128

When in use, the galvanoscope is turned so that the compass needle is parallel *to the coil of wire*.
Test the galvanoscope by connecting it for an instant with a $1\frac{1}{2}$-volt dry cell and observing the deflection of the needle.

Uses of the galvanoscope

1. Field due to a loop and coil.
2. As a test instrument. Connect the galvanoscope as shown below.

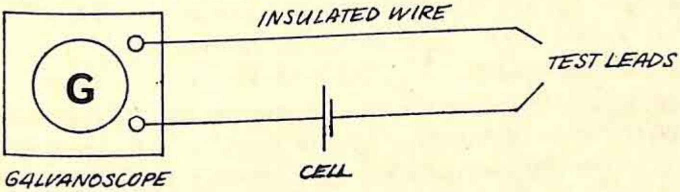


Figure 129

The test leads can be dipped into liquids to test conductivity or they can be joined by solid materials to test their conductivity. Fuses, coils and electrical circuits can all be tested in the same manner.

A bulb continuity tester

A simple bulb tester can be made by screwing a torch bulb holder to a piece of wood and using two terminals on the block

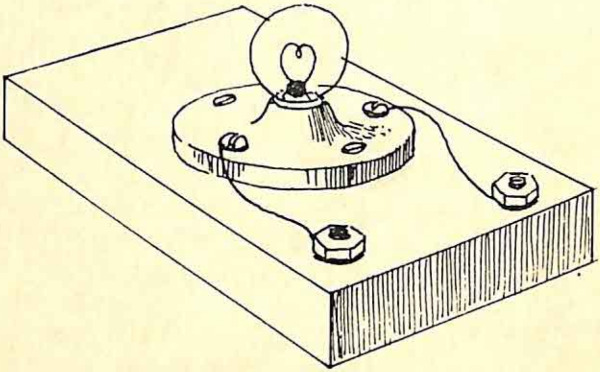


Figure 130

(see Figure 130). This tester is connected in series with a dry cell as shown in the circuit diagram (see Figure 131).

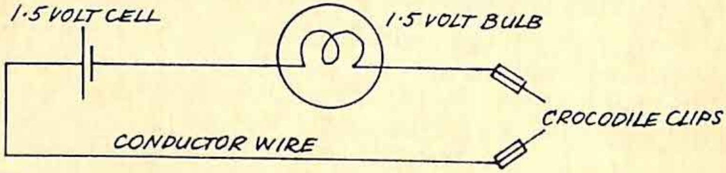


Figure 131

Magnetic field apparatus

Make the top from wood, plywood or hardboard. Screw it or nail it to the sides. Sandpaper all the surfaces well. Drill two ½-inch holes in the positions shown. Take 25 feet of No. 22 insulated wire. Scrape the insulation ¾ inch from one end and

connect to the left hand terminal. Thread the wire carefully and neatly through the ½-inch holes. When half the wire is used, bare a section and connect it to the centre terminal. Continue to wind to the end. Bare the end and connect to right hand terminal.

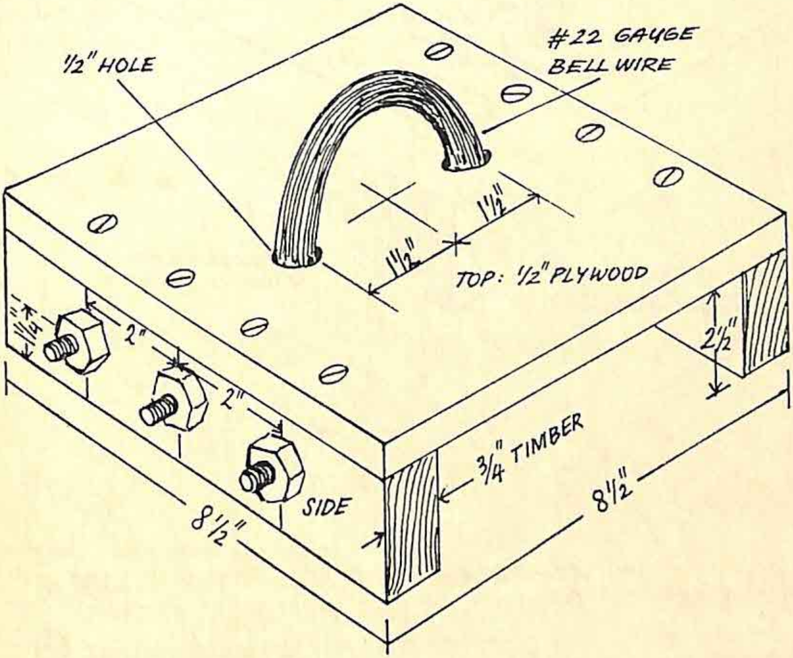


Figure 132

Wind cellotape round the coil. Finish the apparatus with shellac or varnish and rub the surfaces smooth.
Iron filings can be placed on the top to show the field; or alternatively, plotting compasses can be used.

A telegraph set

Figure 133 explains itself. The armature and key are cut from 'banding' metal strip, or from tinplate, from the patterns given below. The electromagnet is wound in the manner previously shown.

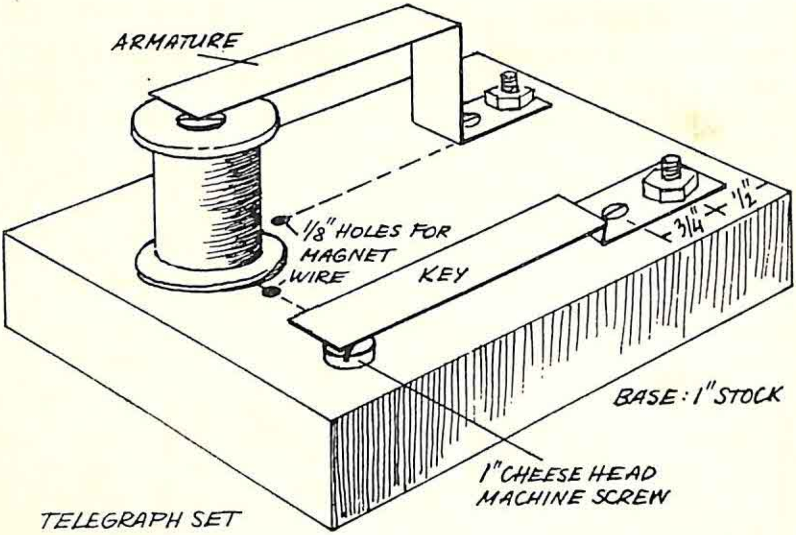


Figure 133

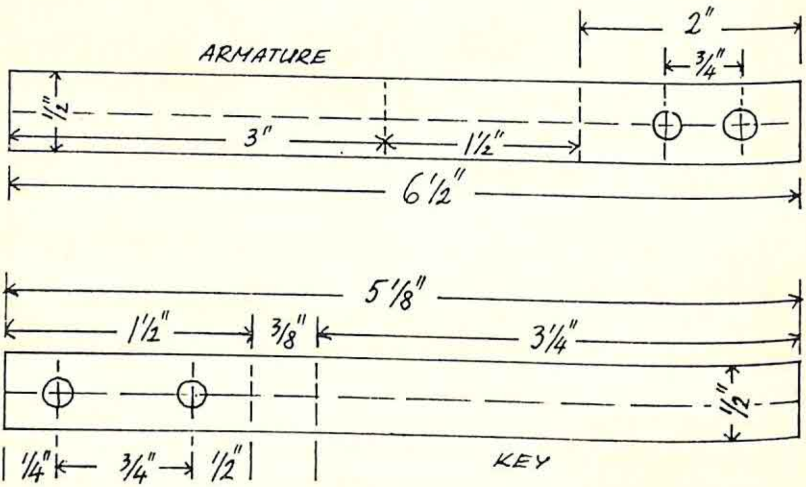


Figure 134

A simple electric motor

Figure 135 shows how the parts are assembled on a wooden base. For the core of the electromagnet use a $\frac{1}{4}$-inch machine screw and insulate it with two layers of cellotape before winding is begun. Use 60 feet of No. 30 insulated wire and when the coil is wound, wind two layers of cellotape over the top.

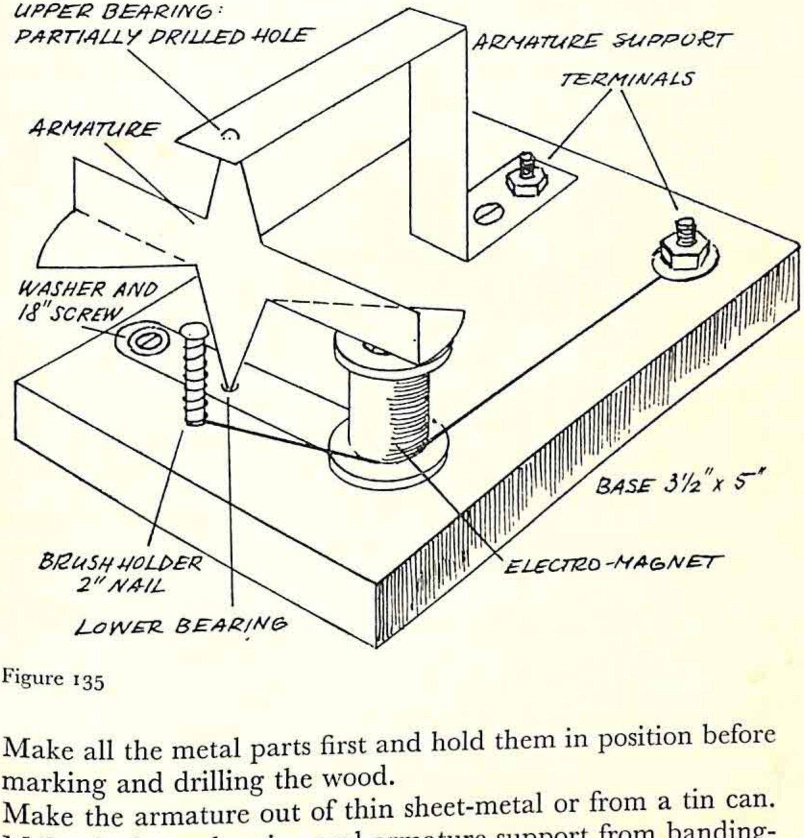


Figure 135

Make all the metal parts first and hold them in position before marking and drilling the wood.
Make the armature out of thin sheet-metal or from a tin can.
Make the lower bearing and armature-support from banding-metal or a tin can. Be careful not to drill through the $\frac{1}{8}$-inch bearings. If the metal is thin it is probably better simply to punch a dent with a dull centre-punch. The armature and bearings can be cut from the patterns shown in Figure 136.
Connect to a 4 volt battery. (The motor should be operated for short periods only.)

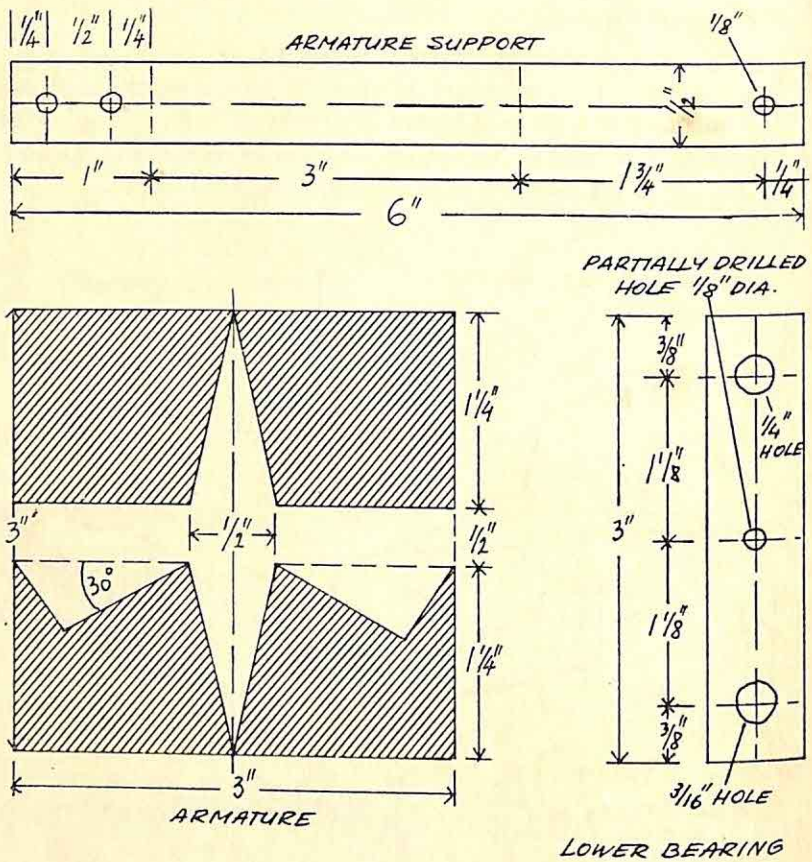
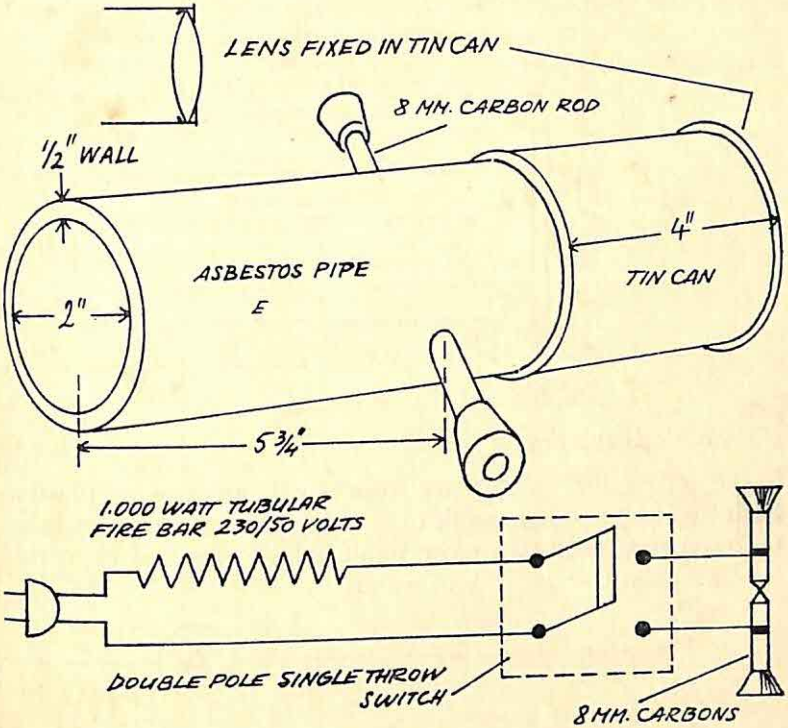


Figure 136

Carbon arc light source

Use a 2-inch asbestos water pipe, 9 inches long, for the light source. Hold it in a retort clamp. Drill holes for the carbon rods opposite each other, $5\frac{3}{4}$ inches from one end. The carbon rods can be bought or, alternatively, the carbon cores of old dry cells can be used. They should be rubbed to a point. Slide a tin can, with a lens fitted in the end, over the asbestos tube for focussing. Insulate the rubber stoppers so that they may be held as the arc is adjusted. 'Strike' the arc by touching the carbons and then pull them a little apart.



WIRING DIAGRAM

Figure 137

NOTE: The arc must always be used in series with a 500- to 1,000-watt resistance:

Demonstrating the laws of resistance

Mount 2-ft. lengths of No. 20 Nichrome wire, No. 28 Nichrome wire and No. 28 Copper wire on a board as shown in Figure 138. Using two dry cells and a bulb in series, the intensity of the light in the bulb shows

(*a*) Variation of resistance with diameter of wire.
(*b*) Variation of resistance with nature of material.
(*c*) If the copper wire is heated while connected to the circuit it will be seen that the hotter the wire the greater the resistance.

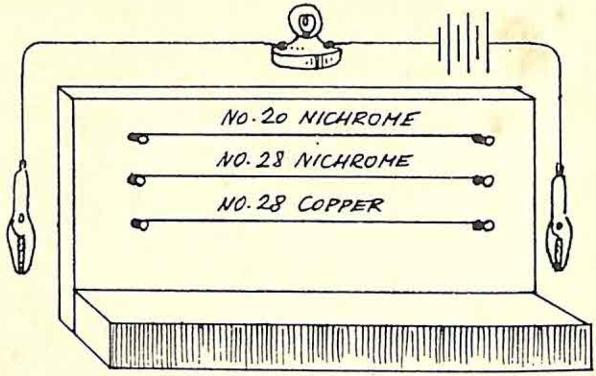


Figure 138

The electrical equivalent of heat

Make top of the calorimeter from wood, asbestos or plastic. Drill two holes wide enough to take the copper stirrer and the thermometer. Drill two more small holes to lead wires to the heating coil. Use 250 ml. of water.

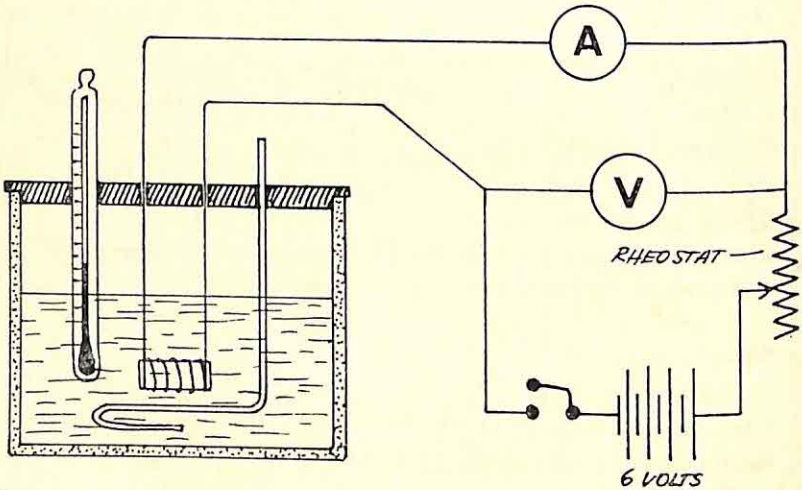


Figure 139

For the heater use a 5-ohm, 5-watt wire coil wound round a porcelain or glass tube. It can hang in the calorimeter on its own leads.

Using the suggested volumes given, a 10-minute heating period

will give a rise in temperature of about 10 degrees. Adjust the rheostat so that the voltage remains constant. Take readings of the ammeter, voltmeter, time, weight of water and temperature rise.

Electromagnetism

Force on a solid conductor in a field

The stirrup is made of stiff copper wire suspended by hooks to copper wire leads, as shown in Figure 140. The leads can be held

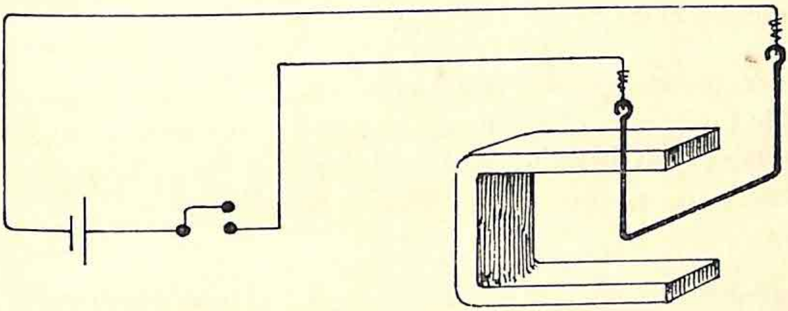


Figure 140

in a retort stand. The connection between the hooks and the copper wire leads must be a good electrical contact yet allow the stirrup to swing freely between the poles of a strong magnet.
The switch is a press switch. The dry cell connections can be reversed.
The hand-motor rule is easily taught with this apparatus.

Force on a liquid conductor in a field

Use a shallow dish. Arrange one copper electrode to dip into the middle of the dish and the second close to the side. Connect the electrodes up to a switch and two dry cells in series.
Place a horse-shoe magnet close to the cell so that its field is vertical.
When a current is passed through the solution the liquid rotates. The rotation of the liquid can be seen better if some powdered cork is sprinkled on the surface.

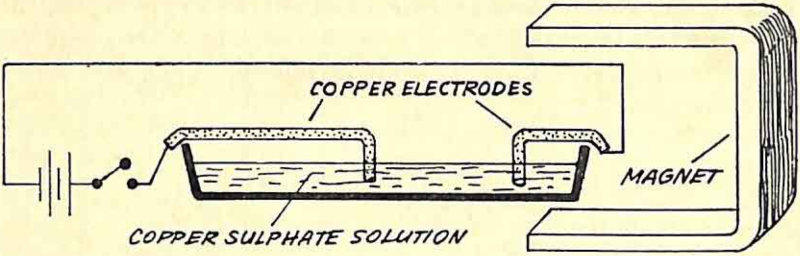


Figure 141

Reversing the connections to the cells of course changes the rotation of the liquid conductor.

Eddy currents and Lenz's law

Find the centre of an aluminium cake tin and punch a small dimple from the inside. Balance the cake tin upside down on a

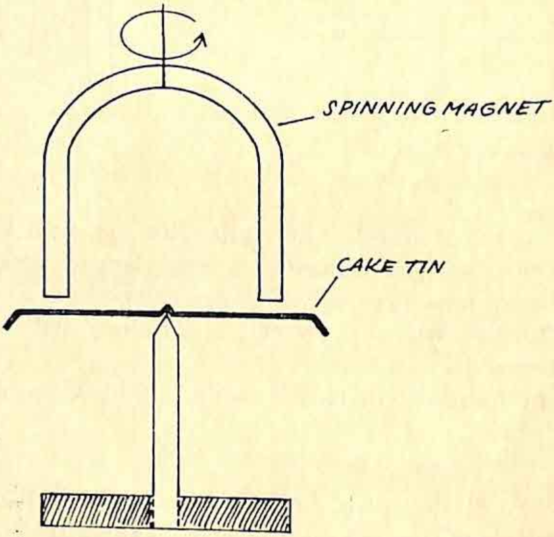


Figure 142

nail fixed in a piece of wood. Grind the end of the nail to an even, sharp point so that the cake tin can spin round easily with the minimum of friction. Paint a black mark on the tin so that any rotation can be seen clearly.

Suspend a strong magnet about $\frac{1}{4}$ inch above the plate. Twist the cord so that as it unwinds the magnet spins. Reverse the spin and note the effect.

An alternative to an aluminium cake tin is a coil shield from an old radio, an aluminium cup or a copper disc.

It may be argued that air currents spin the tin. To disprove this insert a thin card between the magnet and the rotating disc.

Mutual induction

The two coils are each 50 turns of No. 22 *S.W.G.*, *D.C.C.*, copper wire.

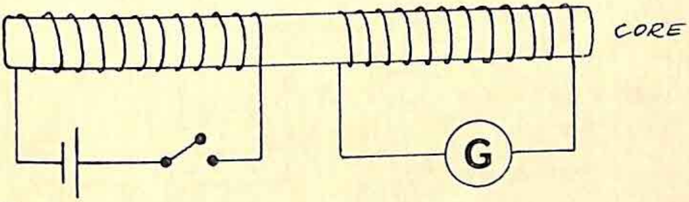


Figure 143

The core is a bundle of nails 4-5 inches long, or a 4- to 5-inch iron bar or pipe.

This effectively shows that there is an induced *e.m.f.* only when the magnetic field is changing.

Simple stroboscope

The stroboscope is of use in many different branches of physics, and is used to arrest (stop) motion. For the disc use a piece of hardboard, 10 inches in diameter. Cut twelve evenly-spaced slits

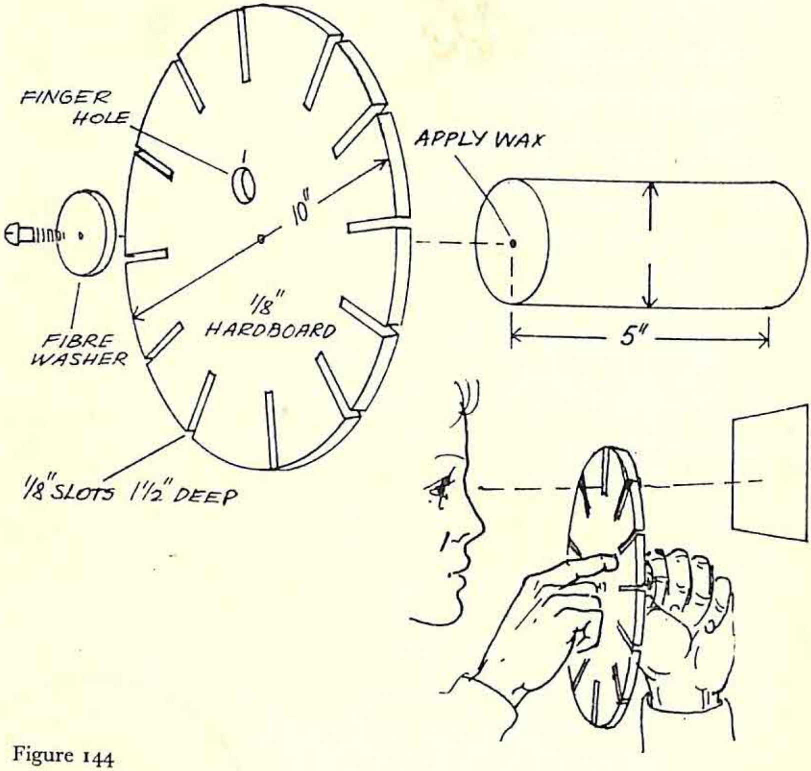


Figure 144

round the circumference, each $\frac{1}{8}$ inch wide and $1\frac{1}{2}$ inches deep. Drill a centre hole to take a No. 6 1-inch round- or flat-headed screw and washer.

The finger hole should be 1 inch in diameter, offset $1\frac{1}{4}$ inches from the centre of the disc.

Screw the disc to a piece of broom handle. Paint the disc a dull black.

To cut the slits, fit two, or even three, blades on a hacksaw to get the $\frac{1}{8}$-inch width.
Little practice is required to use the stroboscope. By using black insulating tape a number of slits can be covered, giving a strobe with 1, 2, 3, 4 or 6 slits as well as the twelve-cut.

A simple overflow can

As Figure 145 shows, this is simply two cans of different sizes. Fill can A to the brim with water. Lower the object into this

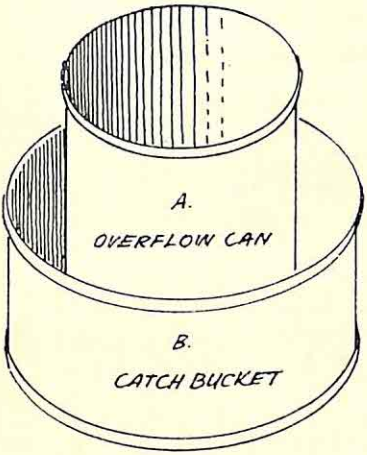


Figure 145

water and catch the volume of water displaced in can B. Find the volume displaced by pouring the water from can B into a measuring cylinder.

Cartesian diver

Divers can be made from glass tubing, the end of a test tube, a medicine dropper, etc. Sometimes a small bulb is blown in the end of the glass tube.
Adjust the air space in each case until the diver just floats.
Place the diver in a bottle nearly full of water and stretch a rubber diaphragm over the top, holding it in position by a rubber band. Press the rubber to sink the diver.

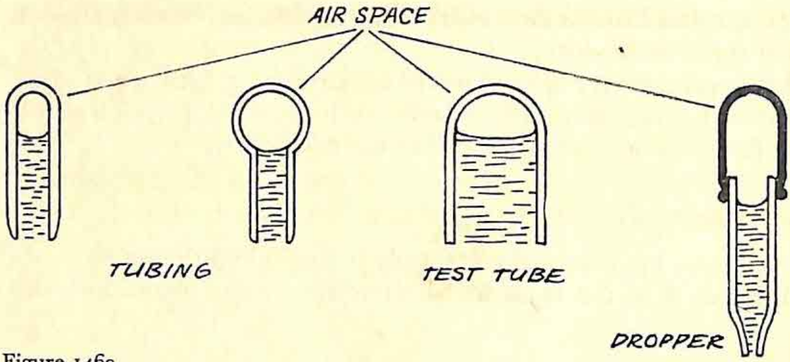


Figure 146a

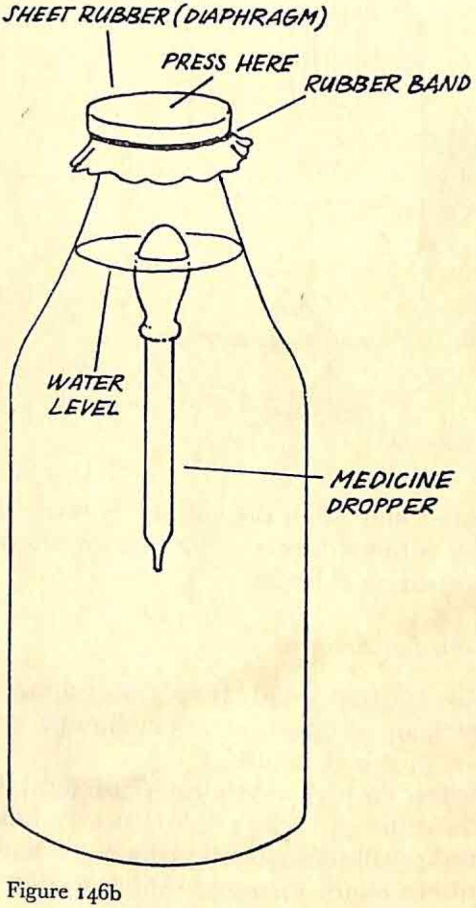


Figure 146b

Alternatively, use a flat-sided medicine bottle. Nearly fill this with water and insert the cork. All that is required to sink the diver is to squeeze the flat sides of the bottle.

Helicopter device

Using a heavy paper or light cardboard, cut out the pattern given in Figure 147. Cut and fold on the lines marked.

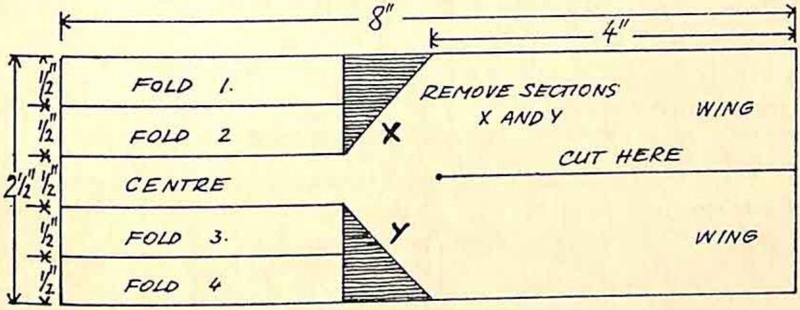


Figure 147

One or two paper clips can be added to get the best results. The device is thrown into the air. On falling, it spins, and the spin reduces the rate of fall.

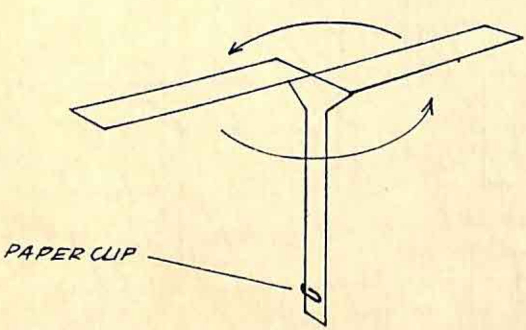


Figure 148

Tin-can steam turbine

Many different types of turbine blades can be constructed from tinplate and be supported over a coffee tin or syrup tin with a

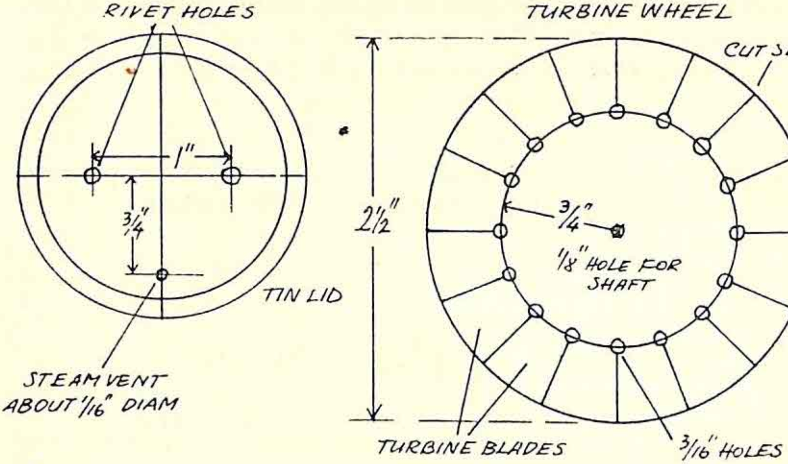


Figure 149

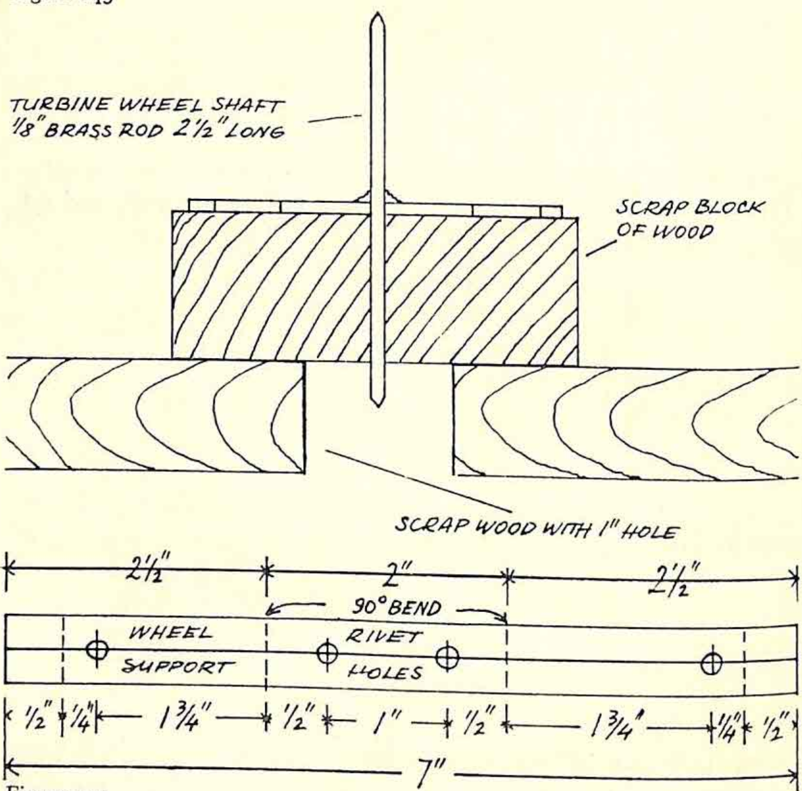


Figure 150

small hole in the lid. The difficulties met with are all concerned with the mounting. The suggestions offered give a stable mounting, so that the turbine will not drift away from the steam jet and the wheel shaft is set perpendicular to the turbine wheel. The supports are riveted or fastened to the lid with small nuts and bolts.

Punch or drill the $\frac{1}{16}$-inch centre hole for the shaft as shown in Figure 149. Note that when very thin gauge metal is used for the turbine wheel, the $\frac{3}{16}$-inch holes are not needed.

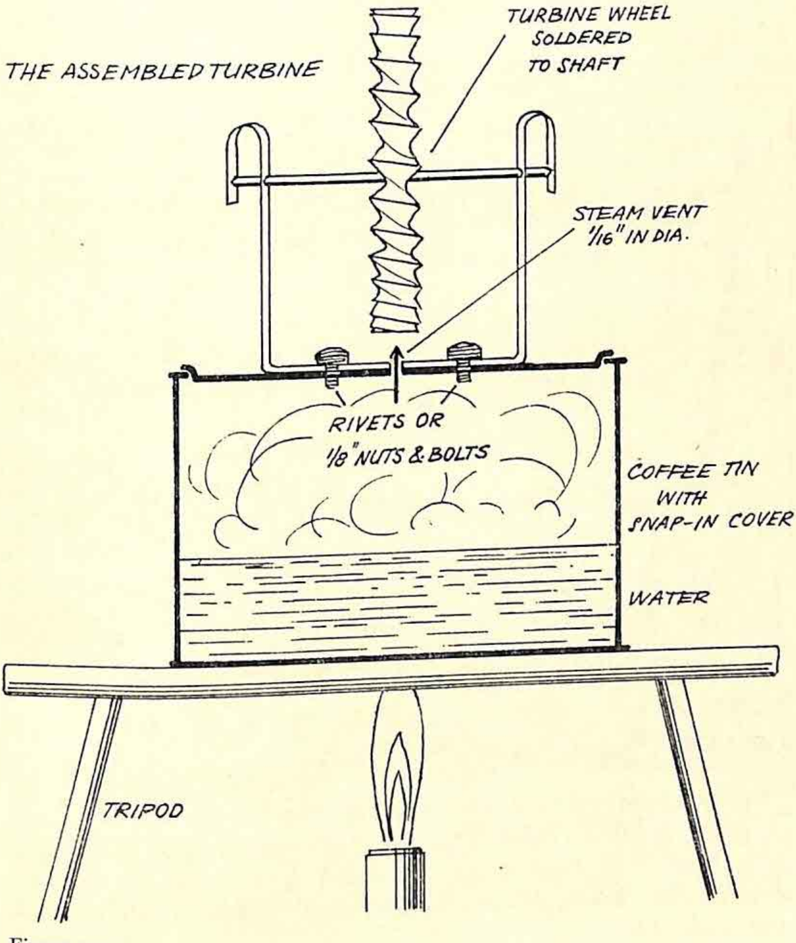


Figure 151

Twist the turbine blades to the desired angle with a pair of flat-nose pliers.

Soldering can be done with a torch or a soldering iron.

Figure 150 shows how to solder the shaft to the wheel, and gives a pattern for the support.

NOTE: The bent-over ends prevent the turbine from 'drifting' from side to side.

Device to demonstrate objects in free fall

The drawing in Figure 152 is self-explanatory.

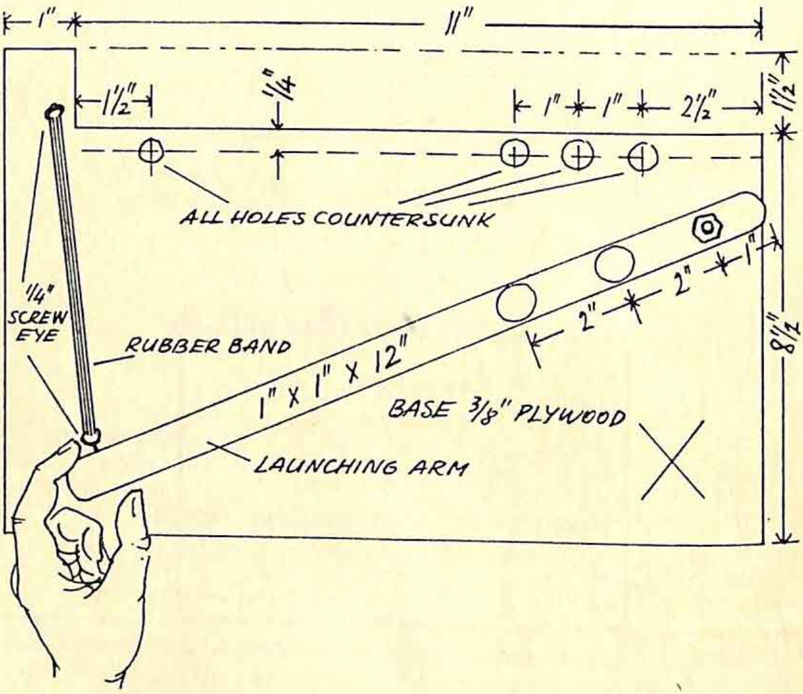


Figure 152

Clamp the device to the top of a table by means of a G-clamp at point X. Place different-sized glass marbles and steel balls (the latter obtained from discarded auto-bearings) on the countersunk holes. The launching arm will strike all balls at the same time.

The trajectories of the balls all vary with their position on the launching board and with their masses, but the rate of fall is the same for all.

Uniform acceleration

The concept of acceleration, as being the rate of increase of velocity resulting in greater distances travelled during successive time intervals, can be demonstrated by using a roller on an inclined plane or a steel ball rolling down a groove.
The simple devices in Figure 153 may be used as alternatives to a grooved board. The inclines should all be about 8 feet long.

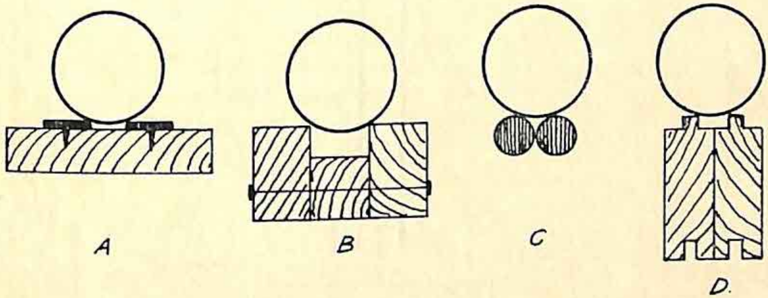


Figure 153

(*a*) Two parallel pieces of banding steel screwed to a board.
(*b*) Two strips of wood with a wood separator.
(*c*) Two steel rods, or glass rods, or pieces of glass tubing.
(*d*) The tongues of two flooring boards.

Alternatively, a 100-gm. weight, if started accurately, will roll smoothly down a long board.

The pile driver

Start the nail straight, with a hammer, into the *end-grain* of a block of wood.
Arrange the tube (which can be of glass or cardboard) over the nail.
The nail is driven a short distance into the wood by the falling weight.

The following readings need to be taken:
1. The height of the cylinder above the nail.
2. The weight of the cylinder.
3. The height of the nail before the blow.
4. The height of the nail after the blow.

The potential energy of the cylinder, the force it exerts, and the force with which the nail resists being driven can all be calculated.

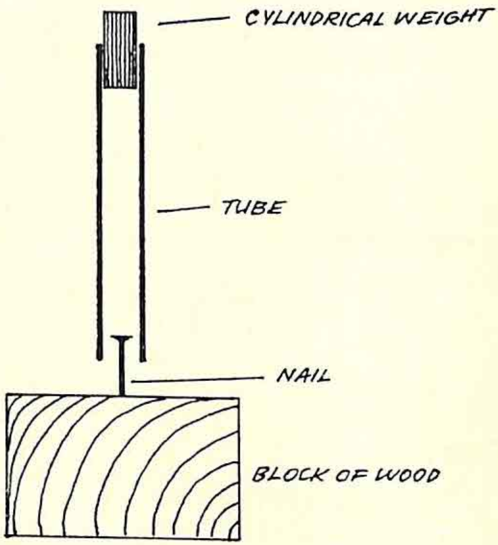


Figure 154

(The resistance of the nail is the force necessary to decelerate the falling weight in the short distance the nail goes into the block of wood.)

Archimedes' Principle

Does a body immersed in a liquid really lose weight, or is its weight merely transferred somewhere else?
This is rarely shown when Archimedes' principle is studied.
A very simple device to show this uses a spring balance and a platform balance, either of the kitchen scale type, or Butchart type.

1. Compare the increased reading of the platform scale with the decreased reading of the spring balance.
2. With the solid immersed, mark the height of the water in the beaker with a sticky label.
3. Now remove the solid and add water until the platform scale is the same reading as it was when the solid was immersed. The water level will now be up to the label again (i.e. apparent difference in weight is equal to the weight of displaced water).

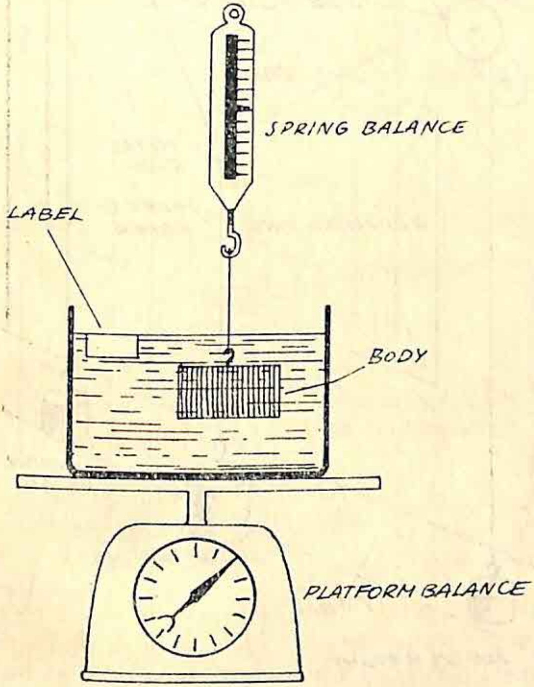


Figure 155

Force board

The force board is best constructed of pegboard so that the position of the pulleys can be changed.
Scale pans can be fitted instead of weights.
The pulleys can be replaced by fixed screws or bolts on to which spring balances can be hooked if desired.

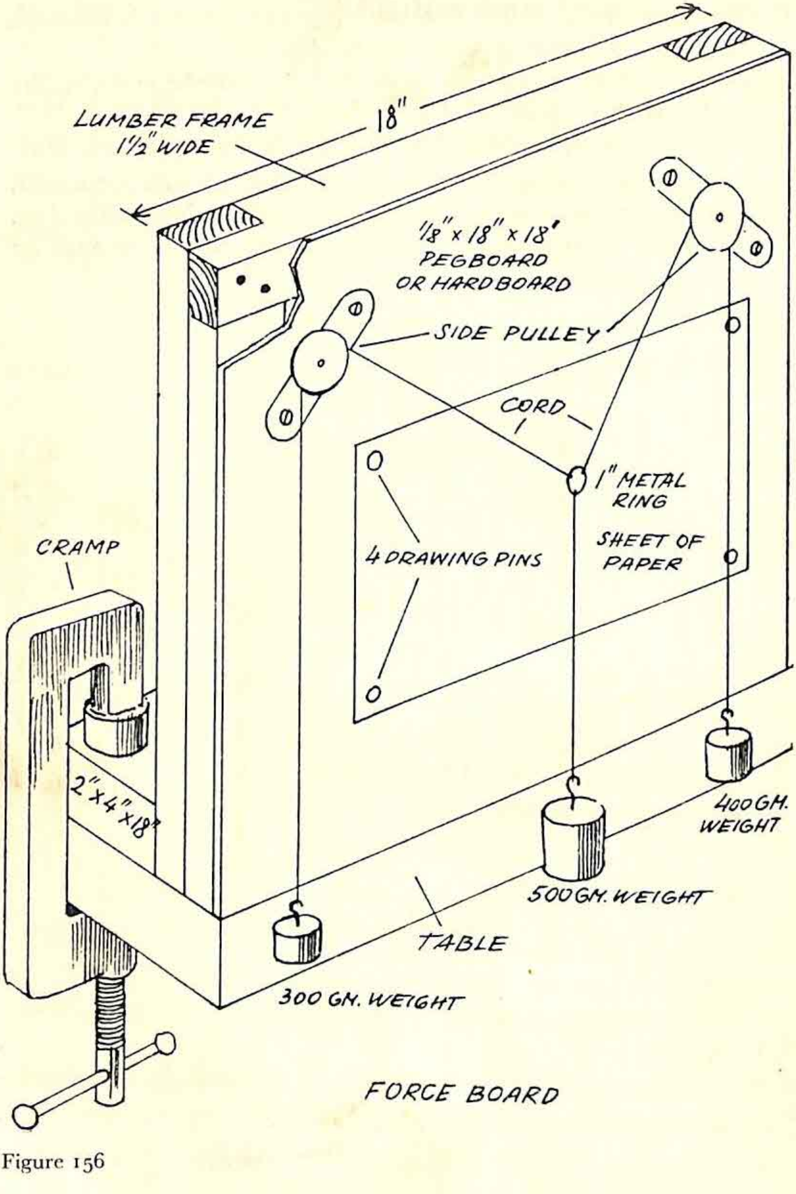


Figure 156

NOTE: Pegboard has innumerable uses (see the Chemistry Section).

Conductometer

This instrument is easily constructed and works well. The drawing in Figure 157 should explain itself: the strips of metal

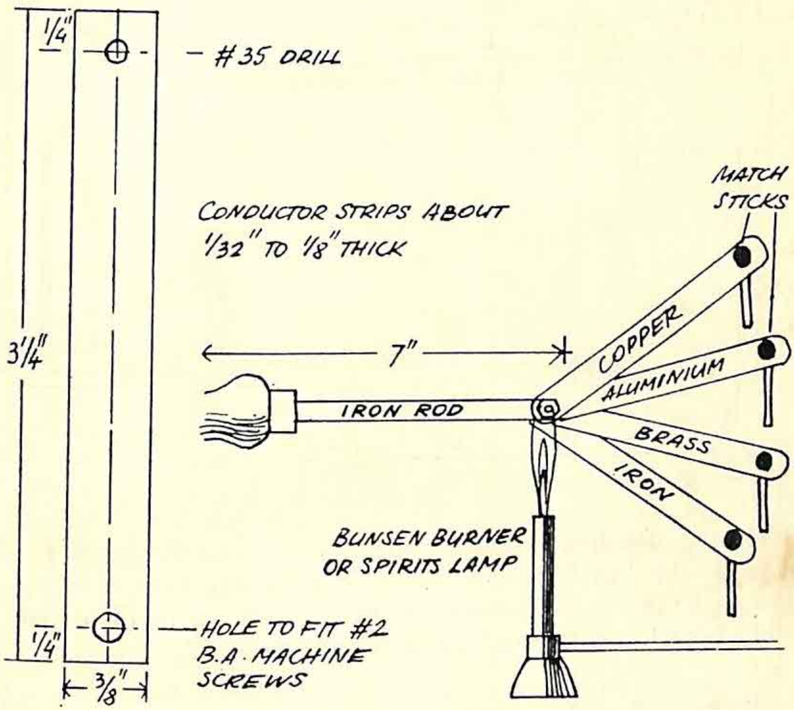


Figure 157

can be cut according to the pattern. They should all be the same thickness.

Make the handle from a broomstick and drive the pointed end of the iron rod into a hole drilled in one end.

The small holes in the ends of the strips must allow the match-stick to pass through but not the match head.

Expansion of metals

A simple apparatus to show that metal expands, is explained

in Figure 158. Screw the metal strip to the top of support A and let it rest lightly on support B.

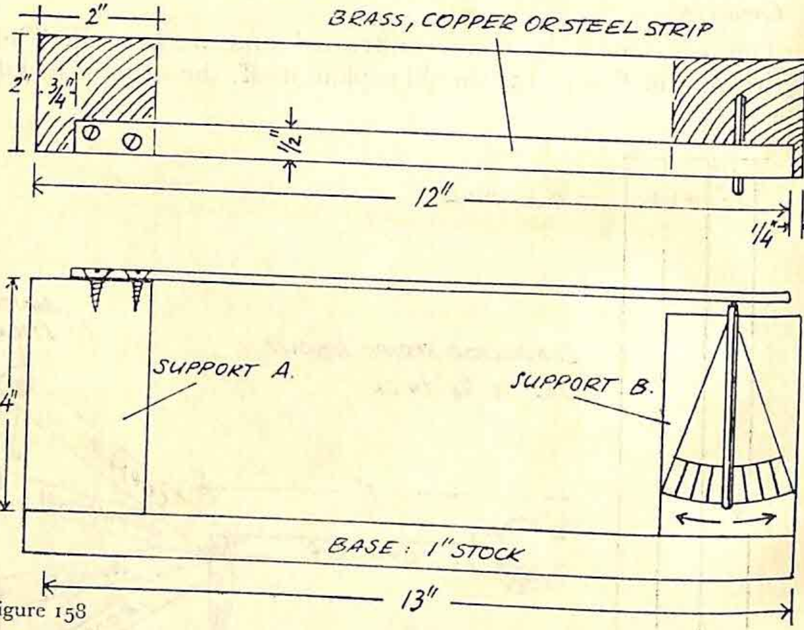


Figure 158

The top of support B must be smooth.

Make the 'needle' from very thin steel wire bent as shown, with the short end between the strip and support B. (The spoke of a bicycle wheel makes an excellent needle.)

Detail of steel wire

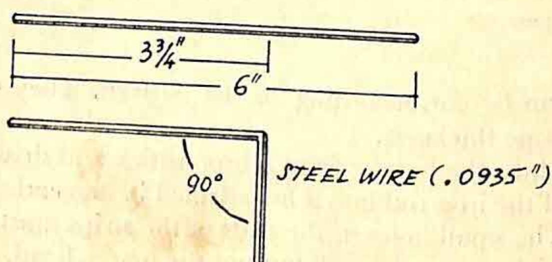


Figure 159

This apparatus shows that different metals expand different amounts. It works well with a spirit burner or candle flame.

To compare expansion directly

Slip an ordinary sewing needle, with a light balanced card-board pointer on it, between the ends of the copper and iron strips. (See Figure 160.)

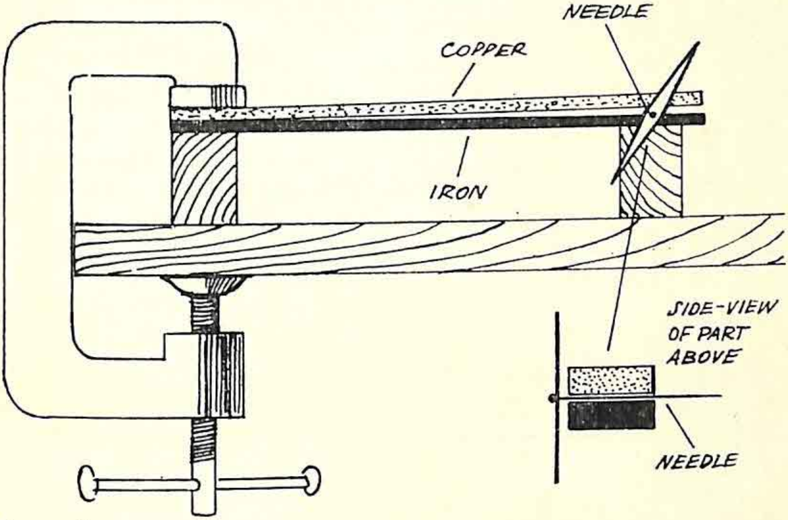


Figure 160

Heat the metals as impartially as possible. The pointer will turn indicating the different expansion rates.

To measure the coefficient of linear expansion of copper

The idea of coefficient of linear expansion is relatively simple to grasp in theory, but is not easy to determine in practice because of the difficulties of measuring the expansion accurately unless micrometer gauges are incorporated in the apparatus.

However, a surprisingly accurate yet simple apparatus is described below.

The measuring device is shown in section B of Figure 161. Essentially it is a piece of stiff copper wire looped round a glass rod. The short arm is 3 cm. from *the point where it rests* under the end of the wire whose expansion is being measured, to the loop. The long arm is 30 cm. long. The centimeter scale shows ten times the expansion. Thus we can measure to 0·005 cm. of the actual expansion.

5

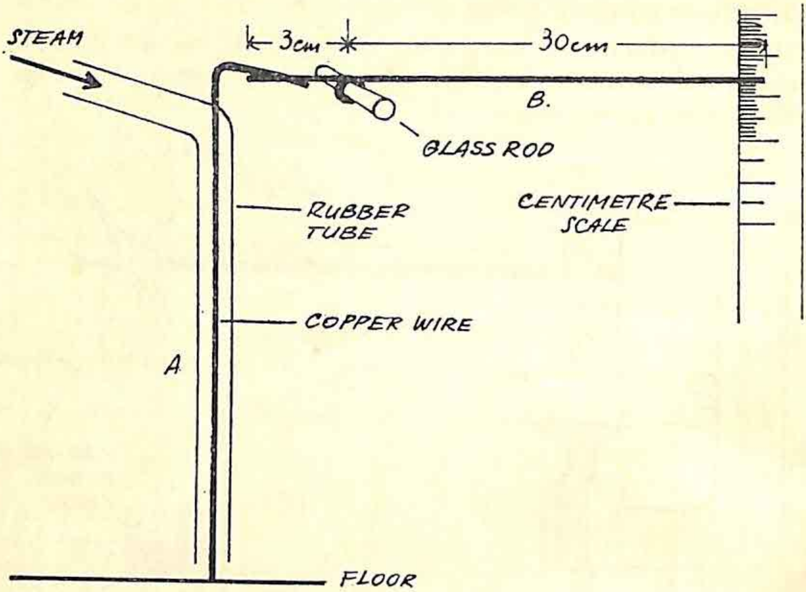


Figure 161

The copper wire whose expansion is being measured is bent at right angles at the top, threaded through the wall of a length of rubber connecting tubing and stands on the floor. Its length can be measured before the experiment.

The temperature rise is from air temperature to the temperature of the steam. Thus all the requirements can be measured. The steam issues fairly safely from the bottom of the rubber tube though a warning should be issued to pupils to keep away from it. A length of wire about 120 cm. long gives good results.

Laws of Reflection and Refraction

A piece of soft board ½ inch thick is an excellent base on which to work. This is cheap and easily obtainable. Use a piece 15 inches by 15 inches and paint top surface with white, plastic-emulsion paint. This provides a firm base in which pins can easily be stuck.

Mirrors Always stick plain mirrors to a block of wood. Cut the block to fit the mirror: there are many good adhesives available,

but any multi-purpose glue should do. The block preserves the backing of the mirror and when the mirror is being used vertically it does not readily fall over.

Reflection There is no doubt whatever that beams of light enable pupils to understand reflection (and refraction) more easily. All other methods are artificial and confuse many pupils. Pins stuck in the board will serve to do the experiments and often are the only means of doing light experiments where apparatus is in short supply.

Black thread stretched over the board serves very well for many experiments and is better than using pins.

The apparatus for simple reflection is shown in Figure 162. Pass

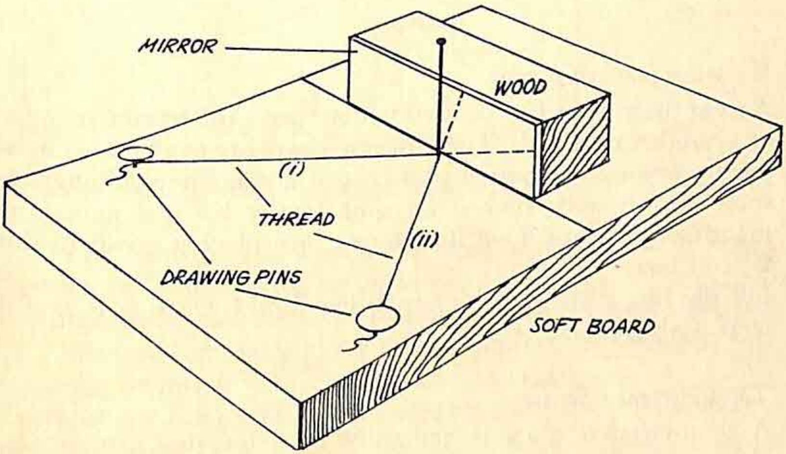


Figure 162

the thread behind the pin, placed close to the mirror. Measure the angles simply by placing a protractor over the threads. Looking in the mirror line thread (ii) up with the reflection of thread (i).

Refraction

The same device can be used for refraction. In this case pass the thread under the glass block, using pins to hold it in position as shown in Figure 163.

The angles can again be determined using a protractor placed over the thread and pencil line.

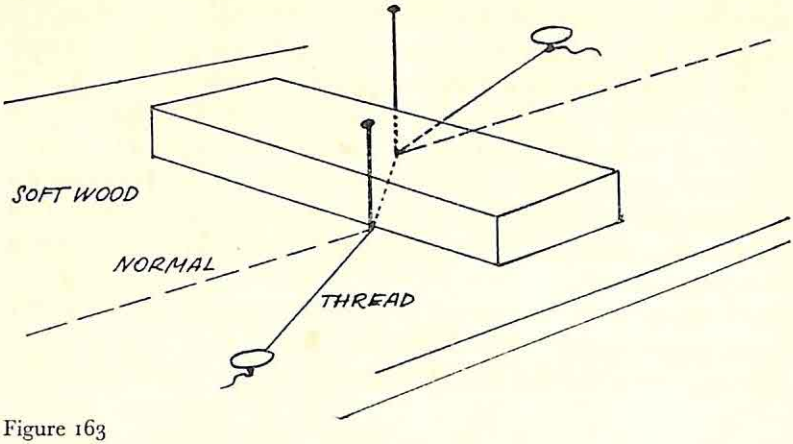


Figure 163

Refractive index of liquids

A clear plastic box can be used to determine the refractive index of a number of liquids. These plastic boxes are available at most science supply companies at a cost of about three shillings, or they can often be picked up quite easily because many toy manufacturers and food distributors are placing goods in this type of box.

Fill the box with water or any other liquid, treating it as if it were a glass block.

Total internal reflection

A semi-circular glass is generally used for this experiment. (Cheese firms are introducing semi-circular plastic packs, and these filled with water or other liquids serve perfectly well.)

Simple optical bench and light source

Fix a length of wood just over 1 metre long and 5 inches wide by $\frac{3}{4}$ inch thick, on to two 5-inch by 2-inch by 1-inch wooden blocks at each end. Screw the metre ruler down one side, as shown in Figure 165, with the zero end flush with the end of the wood board.

Cut a triangular shape in the base of a tin can with a diameter about $3\frac{1}{2}$ inches or more. This is not an easy job, but it can be done with a sharp chisel when the can is supported on a block of wood.

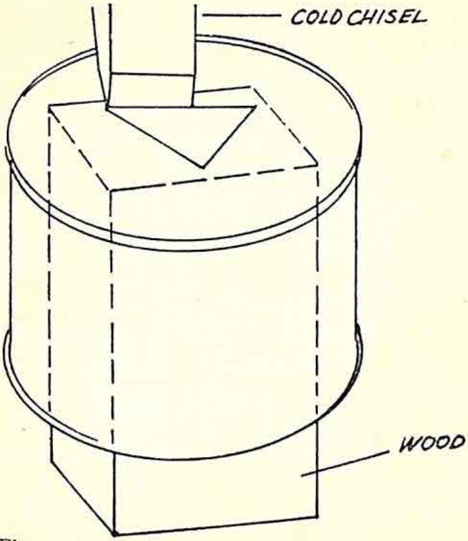


Figure 164

Solder a piece of brass or copper gauze in position on the *inside* of the can.
Fix this can with screws on to the end of the length of wood near the zero mark of the metre ruler.
For the light source use a 60-watt electric light bulb connected by a flex to a light socket and held in position at the open end of the tin by means of a retort stand and clamp.
Paint the bottom of the tin can white so that it acts as a screen when required.
Measurements are easy to make and surprisingly accurate. A variety of lens and mirror holders can be used.

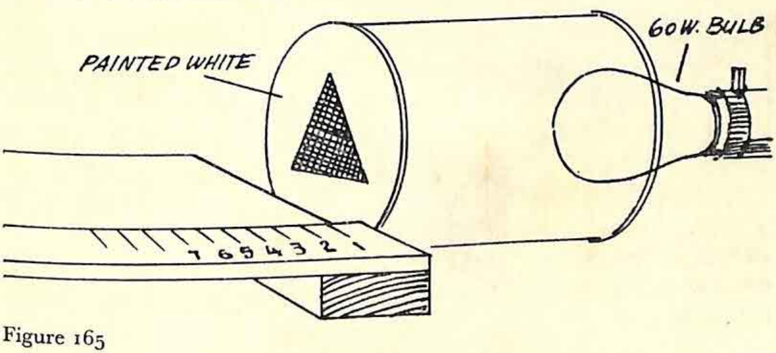


Figure 165

These benches can be produced very cheaply with little expenditure of time and effort and are easily set up for class experiments.

Fine slits

Fine slits to give a thin beam of light should be made with razor blades and drawing pins.

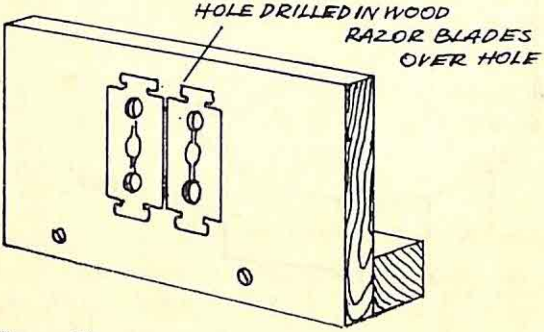


Figure 166

Diffraction grating spectroscope

This is shown in Figure 167.

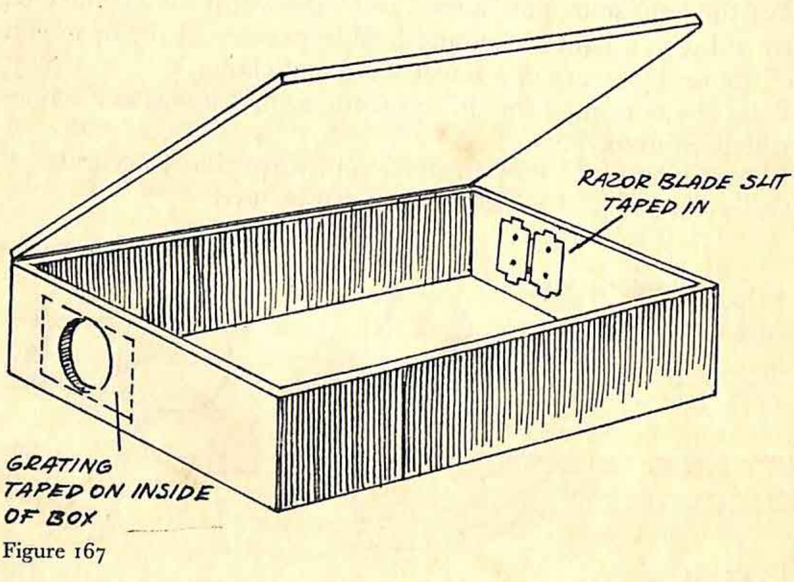


Figure 167

The peep hole should be $\frac{1}{2}$ inch to $\frac{3}{4}$ inch in diameter. The light slit opening should be between 0·05 inch and 0·1 inch between the razor blades (a little experimenting may be necessary).

Offset the peep hole to the side so that the viewer's nose does not get in the way.

Use the new, low-cost, plastic grating which has 13,000 to 14,000 lines per inch.

If a cigar box is not available, a simple, cardboard tube can be used (e.g. a *Smarties* container).

A 10-watt light source may be used to obtain a continuous spectrum. Line spectra can be observed from salts burning in flames, neon signs, argon signs and sodium or mercury vapour lamps.

Simple Experiments in Sound

The drinking straw

Take an ordinary drinking straw and flatten one end. Now cut this flat end to the shape shown in the Figure 168.

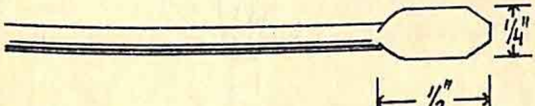


Figure 168

Place the flattened end in the mouth so that the lips hold it firmly and blow to produce a note. A little practice produces a clear note. To show that the pitch depends on the length of the vibrating column of air, snip off 1 inch lengths of the straw with a pair of scissors *as the straw is being blown.*

A musical instrument with eight straws of various lengths can be made.

Vibrating lengths to give a scale of music (one end closed)

	doh	ray	me	fah	soh	lah	te	doh'
Ratio:	1	$\frac{8}{9}$	$\frac{4}{5}$	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{3}{5}$	$\frac{8}{15}$	$\frac{1}{2}$
	4·5"	4·0"	3·6"	3·375"	3·0"	2·7"	2·4"	2·25"
	9·0"	8·0"	7·2"	6·75"	6·0"	5·4"	4·8"	4·5"

Other musical instruments using these ratios can be made from test tubes or bottles filled with different amounts of water. Blowing *across* the tops of these tubes or bottles produces the note. Remember that the air columns above the water and *not* the water in the tubes should have the lengths given.

A singing tube

Use a glass tube about $1\frac{1}{4}$ inches in diameter or larger and about 18 inches long. Fix the wire gauze in the position shown. Heat

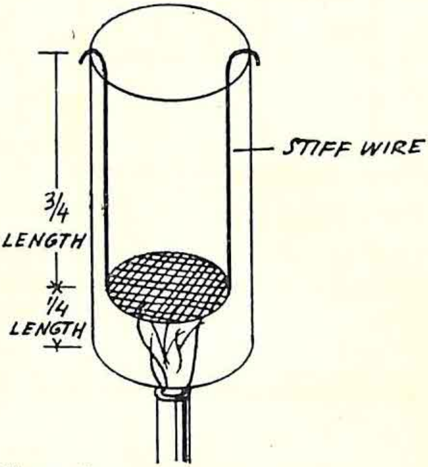


Figure 169

the gauze until the centre is red hot and then remove the tube from the flame. A note, or more accurately a howl, is produced.

Interference in sound

It is not often realized that the waves emerging from the prongs of a tuning fork interfere in all directions and effectively cancel along four lines.

Rotate a vibrating tuning fork over a resonance tube (adjusted to resonate with the fork).

In the figure the fork is viewed end on. In positions (*a*) and (*b*) the tube will respond normally, but in position (*c*) no response will be heard.

For resonance experiments in the laboratory use $\frac{1}{2}$-inch water piping standing in a measuring cylinder. The pipe should be

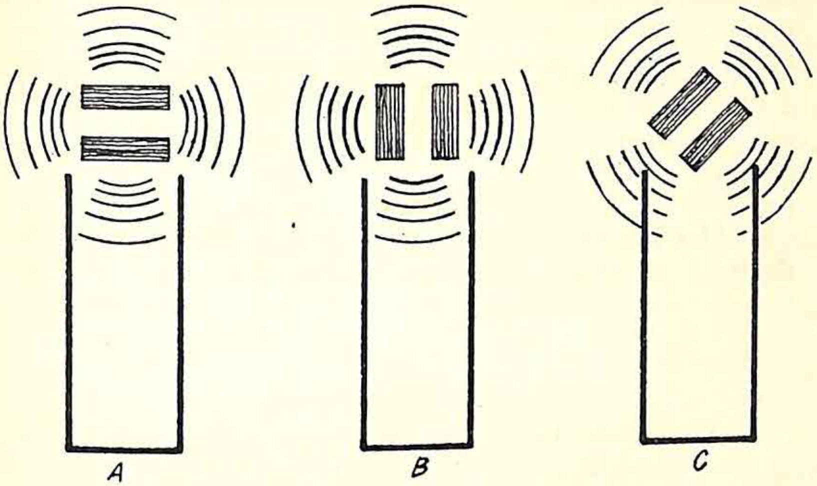


Figure 170

about 20 inches long and the measuring cylinder 12 inches tall. Use a 'G' tuning fork with a frequency of 384 vibrations per second. On the whole pupils seem to hear resonance more readily with a 'G' tuning fork than with middle 'C'.

Spirit burner

Most teachers working in a well-equipped laboratory tend to deride a spirit burner, yet it is cheap, easily made and can be more effective than the bunsen burner when gentle heat is required.

Any metal-capped bottle or can will serve. Punch a hole in the cap. The best results are obtained if the wick fits the hole tightly. Two or three strands of cotton waste (or old shoe laces) make a wick.

Test-tube rack

Most test-tube racks are too tall and test-tubes tend to slip out too easily and are broken. The most convenient rack is made to the dimensions given in Figure 171.

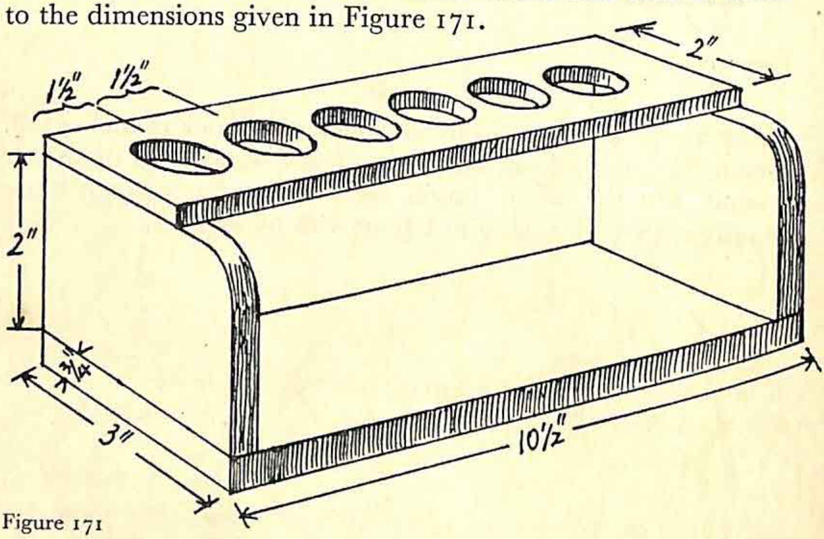


Figure 171

Make the top from ⅜-inch plywood. The holes should be ¾ inch in diameter. This rack is designed for use with 125 by 12 mm. Pyrex tubes. No countersunk holes are required in the base because the 2-inch gap between top and bottom will not allow the tubes to slip (although they can be made if desired). If countersunk holes are made in the base then the top piece must be fastened to the base for drilling so that the holes fall above and below each other. The ¾-inch base is rigid enough

and heavy enough to prevent the rack falling over. A convenient funnel-holder and support can be made by screwing a piece of wood to the end of a test tube rack as shown in the figure. Use a piece of wood $\frac{3}{4}$ inch by $\frac{3}{4}$ inch and 7 inches long.

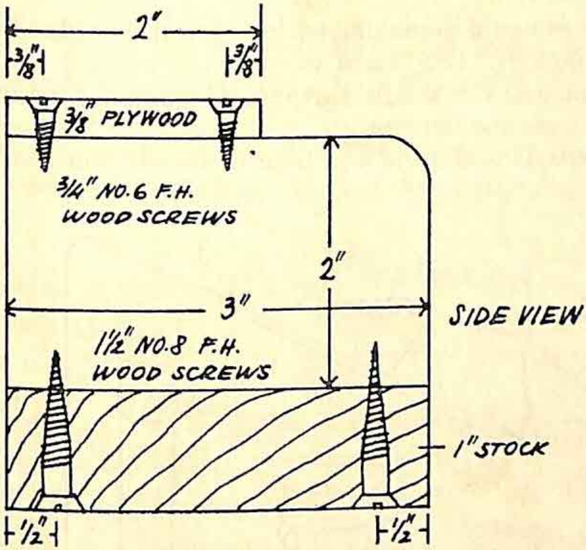


Figure 172

Filter funnel-holder

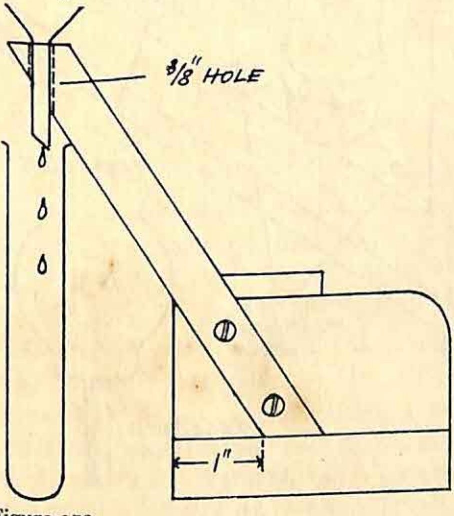


Figure 173

Cut the ends, drill holes for the screws and the funnel, and fix the strip to the rack by means of $1\frac{1}{4}$-inch screws.

Terry clip/Pegboard apparatus rack

This device is most useful in making various 'set-ups' needed in chemistry and biology. The board described is a small one, 12 inches by 8 inches: this should be quite adequate for many small-scale and test-tube 'set ups'.

Assembly Fix parts C and D to the base first, with flat-head

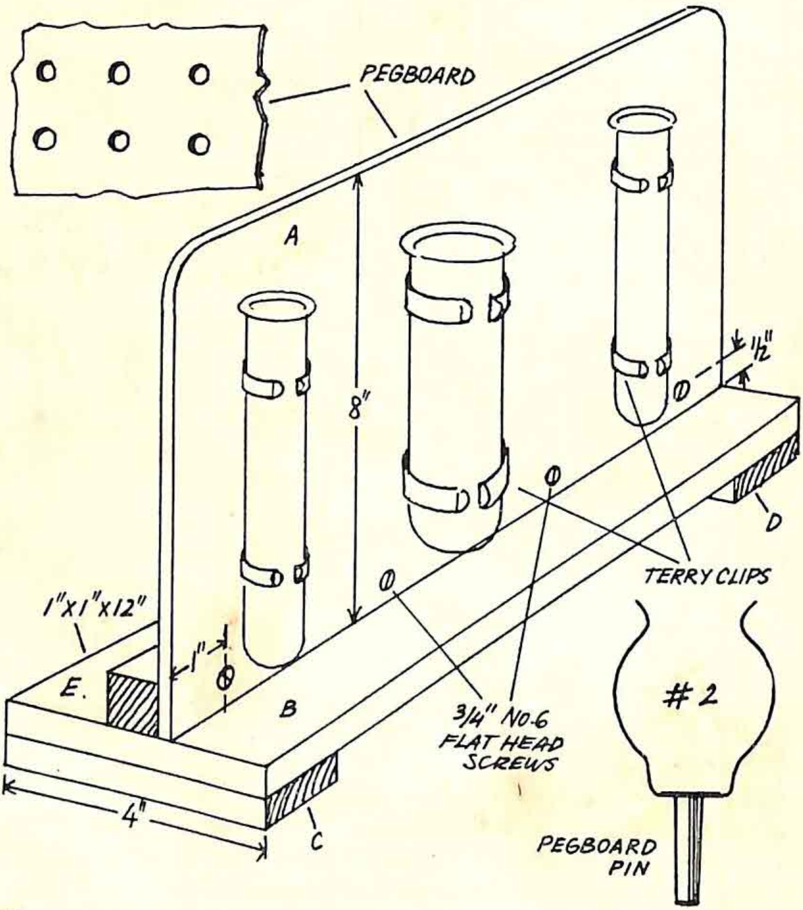


Figure 174

$1\frac{1}{2}$-inch No. 8 screws. The cleat (part E) should come next and the pegboard should be screwed to this. The construction is shown in Figure 174. The pegboard (A) should be fastened to the cleat (E) with four flat-head screws ($\frac{3}{4}$-inch No. 6) evenly spaced.

The Terry clips come in sizes No. 000 to No. 5, all costing a few pence. They are available with or without pegboard pins.

Simple models of atomic structure of elements

The model in Figure 175 can be made from easily available

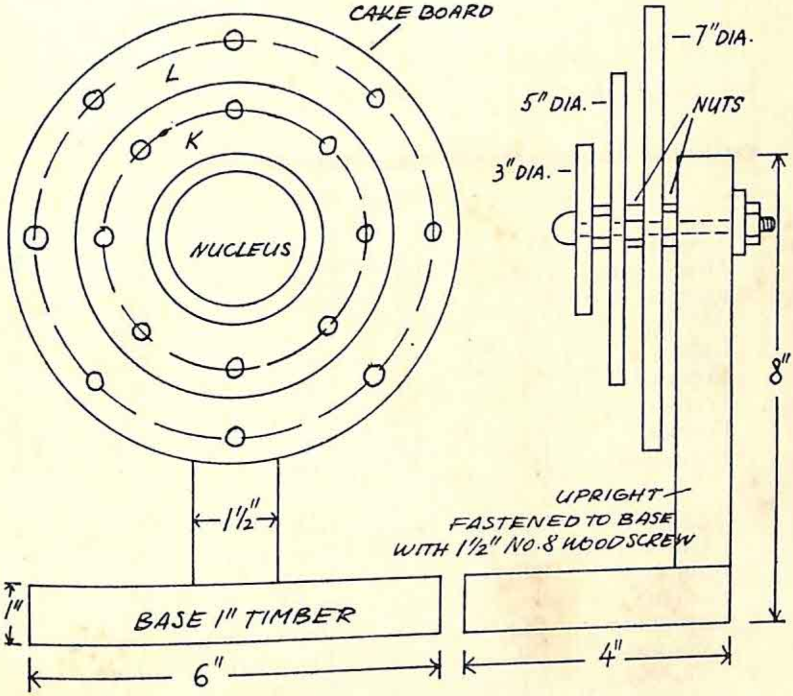


Figure 175

materials. Use a 3-inch diameter circle of plywood as the nucleus and either hardboard or cake boards for the *K*, *L* and *M* shells (only the *K* and *L* shells are shown in Figure 175. If hardboard is used, holes should be drilled to take brass paper

fasteners, which represent the electrons. If cake boards are used, drawing pins can be stuck in to represent electrons. The nucleus should be locked in position by using a nut. Place washers between the remaining shells, so that they can rotate.

Paint the nucleus black with blackboard paint so that the number of protons and neutrons can be chalked in.

To get the illusion of the electrons rotating around the nucleus while apparently remaining in fixed positions, use the stroboscope described on page 116.

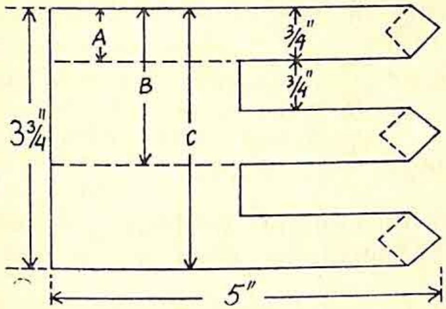
Spin the shells and rotate the stroboscope until the electrons are fixed. This requires some practice, but most students can usually manage it.

Valency cut-outs

Valency of Common Elements and Radicals

Aluminium	Al	+3	Lead	Pb	+2
Ammonium	NH_4	+1	Magnesium	Mg	+2
Barium	Ba	+2	Mercuric	Hg	+2
Calcium	Ca	+2	Mercurous	Hg	+1
Cupric	Cu	+2	Nickel	Ni	+2
Cuprous	Cu	+1	Potassium	K	+1
Ferric	Fe	+3	Silver	Ag	+1
Ferrous	Fe	+2	Sodium	Na	+1
Hydrogen	H	+1	Zinc	Zn	+2
Acetate	$C_2H_3O_2$	−1	Iodide	I	−1
Bicarbonate	HCO_3	−1	Nitrate	NO_3	−1
Bisulphate	HSO_4	−1	Nitrite	NO_2	−1
Bromide	Br	−1	Oxide	O	−2
Carbonate	CO_3	−2	Permanganate	MnO_4	−1
Chlorate	ClO_3	−1	Phosphate	PO_4	−3
Chloride	Cl	−1	Sulphate	SO_4	−2
Hydroxide	OH	−1	Sulphide	S	−2
Hypochlorite	ClO	−1	Sulphite	SO_3	−2

Use the master pattern shown opposite. Use different colours of felt or flannel as required.



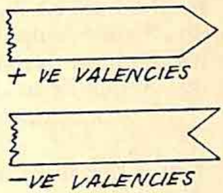


Figure 176

Precipitates and suitable solvents

Below is a list of solvents and a large number of common substances. Reference from the substance list to the number of the solvent is easily made.
Example: '*Bakelite 2, 20, 45*' means that bakelite is dissolved by acetone, ethyl dichloride or *turpineol*.

Solvents

Salts are applied in aqueous solution unless otherwise stated.

1. Acetic acid
2. Acetone
3. Alcohol
4. Ammonium acetate (alkaline)
5. Ammonium chloride
6. Ammonium fluoride (dry)
7. Ammonium hydroxide
8. Ammonium nitrate
9. Ammonium oxalate
10. Ammonium sulphate
11. Ammonium sulphide
12. Ammonium tartrate (alkaline)
13. Benzene
14. Carbon disulphide
15. Carbon tetrachloride
16. Castor oil
17. Chloroform
18. Diacetone alcohol
19. Ethyl alcohol
20. Ethyl dichloride
21. Ferric acetate
22. Ferrous sulphate
23. Hydrochloric acid
24. Lead acetate
25. Mercuric nitrate
26. Naphthene
27. Nitric acid
28. Oxalic acid
29. Potassium carbonate
30. Potassium chlorate
31. Potassium cyanide
32. Potassium hydroxide
33. Potassium iodide
34. Potassium sulphide
35. Potassium sulphide (yellow)
36. Silver nitrate

37. Sodium carbonate
38. Sodium hydroxide
39. Sodium phosphate
40. Sodium sulphide
41. Sodium thiosulphate
42. Sulphuric acid (concentrated or fuming)
43. Sulphuric acid with nitric acid
44. Turpentine
45. Turpineol
46. Water
47. Xylene

Key. The numbers indicate listed solvents: hyphens (-) successive treatment; commas (,) alternative treatment; h, hot; c, concentrated; d, dilute.

Precipitate	Solvents
Aluminium oxide	32ch-46-23, 38ch-46-23
Ammonium chloride	46h
Ammonium chloroplatinate	46h
Ammonium phosphomolybdate	46h, 32, 38
Antimony	27-46-23
Antimony pentasulphide	11, 23, 35
Antimony tetroxide	23h
Antimony trisulphide	11, 23c, 32d, 34, 35
Asphalt	2
Bakelite	2, 20, 45
Barium carbonate	23, 27
Barium chromate	23, 27
Barium sulphate	42h, 43h
Beeswax	2, 3, 13, 44
Bismuth	27d
Bismuth carbonate	23, 27
Bismuth chromate	27
Bismuth nitrate	27
Bismuth oxide	23
Bismuth sulphide	27ch-46-14
Bitumen	26
Cadmium carbonate	27d
Cadmium oxide	23, 27, 42, 43
Cadmium sulphide	23, 27 43dh
Calcium carbonate	23d, 27d
Calcium sulphate	19, 10dh
Camphor gum	19, 20
Caoutcouc	26
Castor oil	20, 47
Cellulose acetate	17, 18
Cellulose nitrate	2, 18
Chatterton's compound	2, 3, 13, 14, 44, 47
Chromium	36 dry+27

Chromium oxide	27+30+36 or 24, 36 dry h+1
Cobalt	27
Cobalt hydroxide	5
Colophony	16, 18, 19
Cupric hydroxide	1, 7, 23, 27, 42
Cupric sulphide	23, 27h
Cuprous oxide	7, 23, 27, 42
Ester gum	16, 20
Gold	23+27
Gold sulphides	31, 35
Gum camphor	19, 20
Gum lac	20
Gutta-percha	17
Iron acetate	23
Iron hydroxide	23d, 27d
Iron oxide	23c
Iron phosphate	23
Iron sulphide	23
Japan wax	2
Khotinsky cement	44
Lead carbonate	27d
Lead chloride	46h
Lead oxide	27d
Lead phosphate	27
Lead sulphate	4, 27, 32h
Lead sulphide	23h, 27c
Linseed oil	46h
Magnesium dioxide	28+42h
Magnesium oxide	23d, 27d, 43d
Magnesium sulphate	46h
Manganese sulphate	46h
Manganese sulphide	23d, 27d, 43d
Mastic dammar	15, 19, 20
Mercuric chloride	46
Mercuric chromate	23, 27ch
Mercuric oxide	23, 27
Mercuric phosphate	23, 27
Mercuric sulphide	34+32
Metastannic acid	38
Nickel	27
Nickel oxide	23
Nickelous sulphate	46h
Paraffin wax	20, 47
Picien wax	13, 14, 17, 44
Potassium chloride	46h
Potassium sulphate	46h
Resin	2, 17, 20
Rubber	2

A killing jar

Specimens should not be left in the killing jar longer than four to six hours because over longer periods the insects become brittle and the colours fade. Many butterflies fold their wings below the body when dying. These creatures should be moved very quickly after death and the wings folded up over the back. Keep the inside of the jar dry. Carbon tetrachloride should be added to the absorbent cotton.

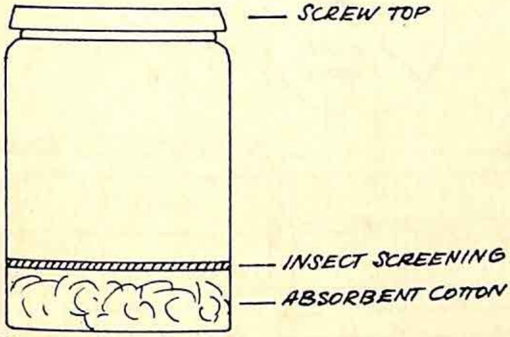


Figure 177

Use different jars for different types of specimens.
Use a killing tube (made from a test-tube and cork for small insects).

Insect net

An insect net can be made easily from heavy-gauge wire, a broom handle, cotton or nylon netting and a metal ferrule to clip the wires on to the broom handle. (A hose clamp makes a good ferrule.)

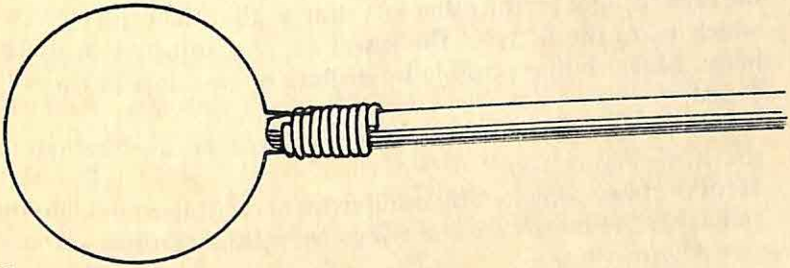


Figure 178

Instead of a metal ferrule, stiff wire can be wrapped around the handle to make a wire ferrule.

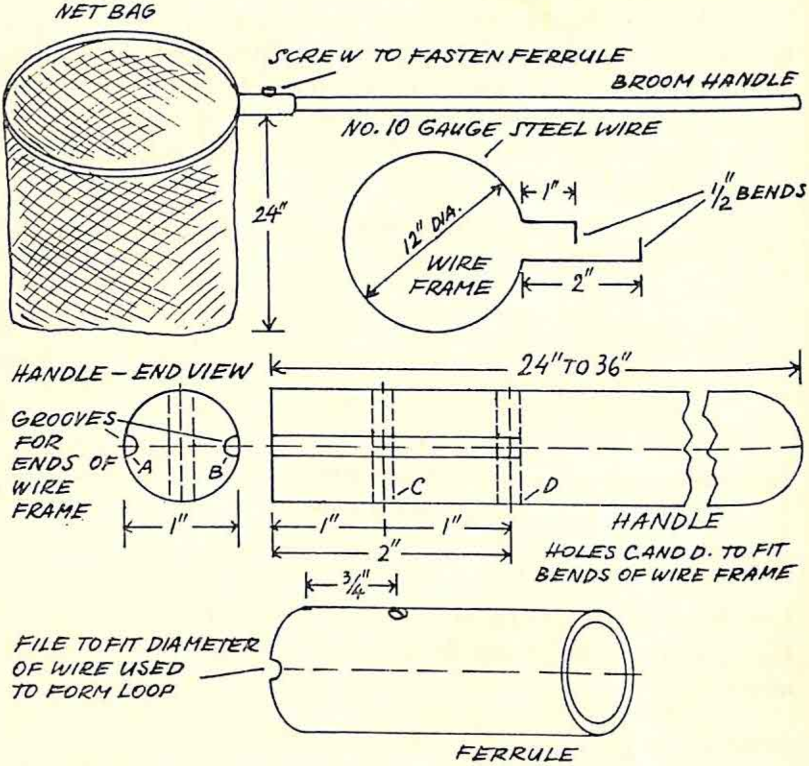


Figure 179

Adjustable spreading board

Make the two tops A and B from ½-inch softboard. Fix one of the tops (B) and let the other (A) slide so that the centre groove which takes the body of the insect can be adjusted to fit the body. Make sliding possible by drilling of two slots in the softboard.

The tops can be made of plain softboard or sections cut as shown in Figure 180.

Hold the insects in place by using strips of cardboard or celluloid pinned in position over the wings by means or ordinary pins (see Figure 181).

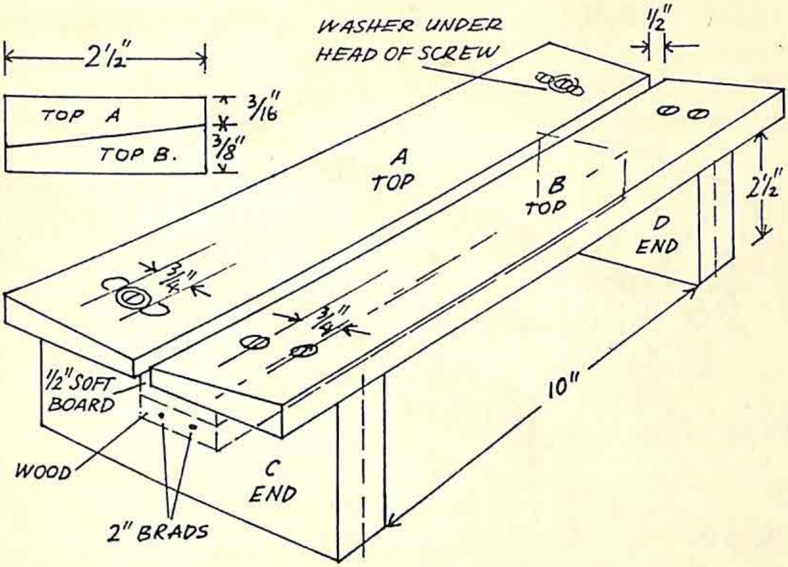


Figure 180

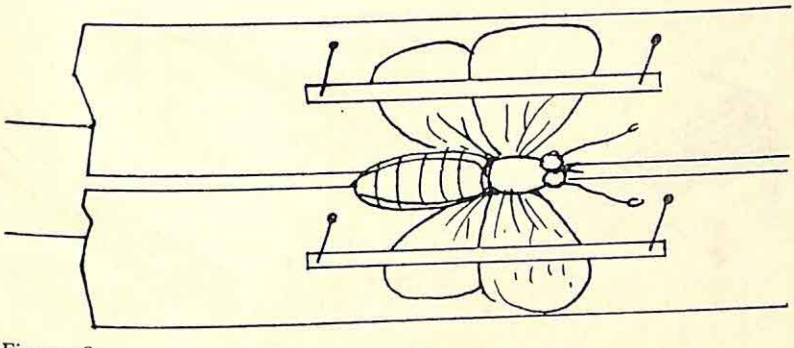


Figure 181

Simple spreading boards

(*a*) *From softboard.* Make the first from a piece of softboard 4 inches by $3\frac{1}{4}$ inches. Cut the groove to take the body of the insect $\frac{1}{4}$ inch wide and $\frac{1}{4}$ inch deep, as shown in Figure 182. All flat-head wood screws used should be No. 6, $\frac{3}{4}$ inch long.

(*b*) *From corrugated cardboard.* Figure 183 should be self-explanatory.

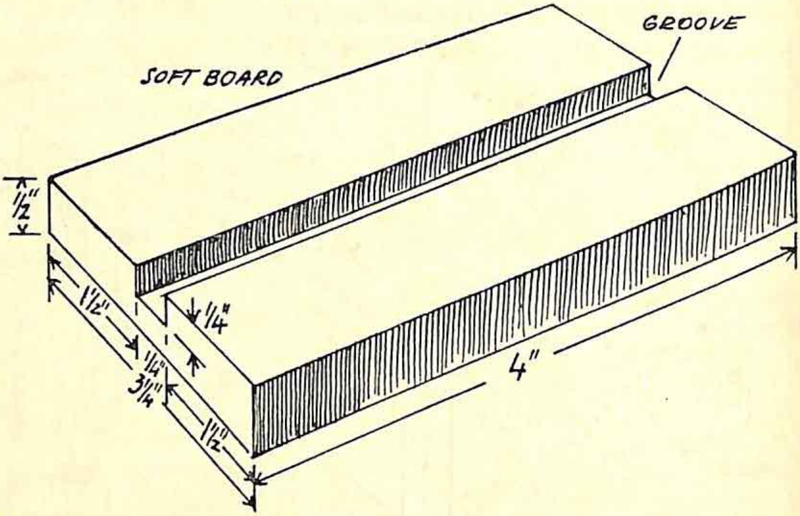


Figure 182

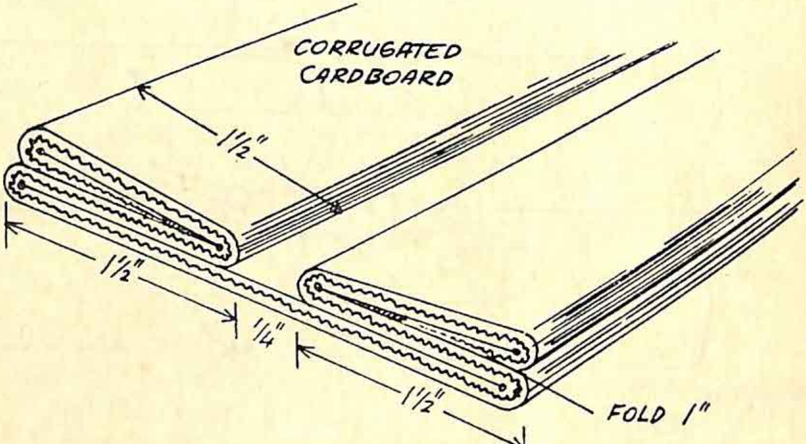


Figure 183

Cut the cardboard $11\frac{1}{4}$ inches wide. The central groove can vary according to your needs.

After the material is cut to size and folded to shape as shown in the figure, it may be glued or stapled together.

Simple animal cage

Figure 184 shows clearly how to make this. Hold the water bottle in place by means of tape or stout rubber bands. Make a small hole in the mesh of the food cover to take the water-drip-tube.

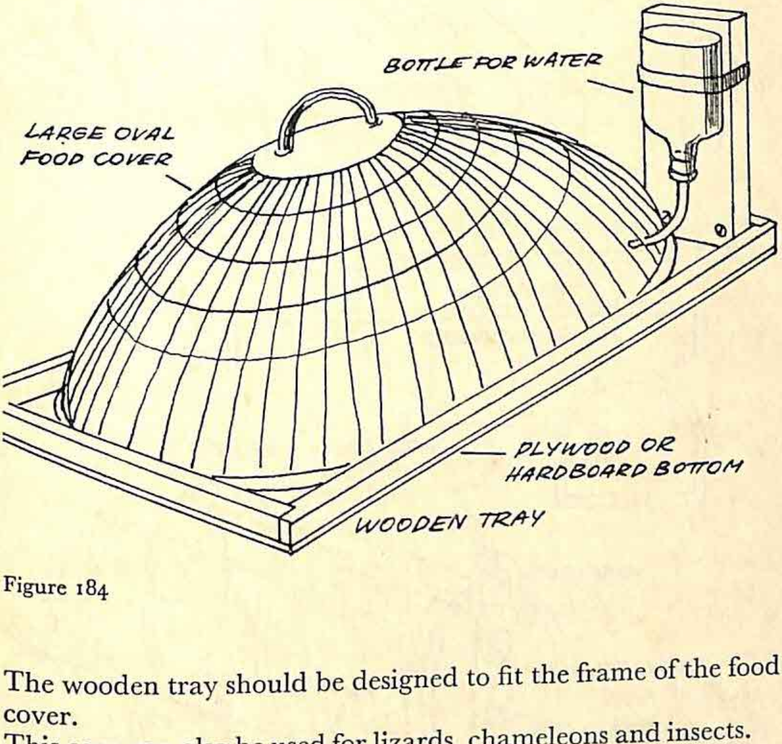


Figure 184

The wooden tray should be designed to fit the frame of the food cover.

This cage can also be used for lizards, chameleons and insects.

Insect collection box

Make this from three tin cans of the same size. Remove all dents and sharp edges and then fix the two wire loop holders and wire loops to these cans as shown. Solder or rivet the loop holders.

Middle section B. Remove both ends of the tin can. Cut the cylinder on the seam. Remove 1 inch from both edges where the seam was formerly. Fold the edges as shown in the figure (allowing about $\frac{1}{4}$ inch for this hem). Now solder Can B to Can A to fix it in position. Punch vent holes in Can A and Can C.

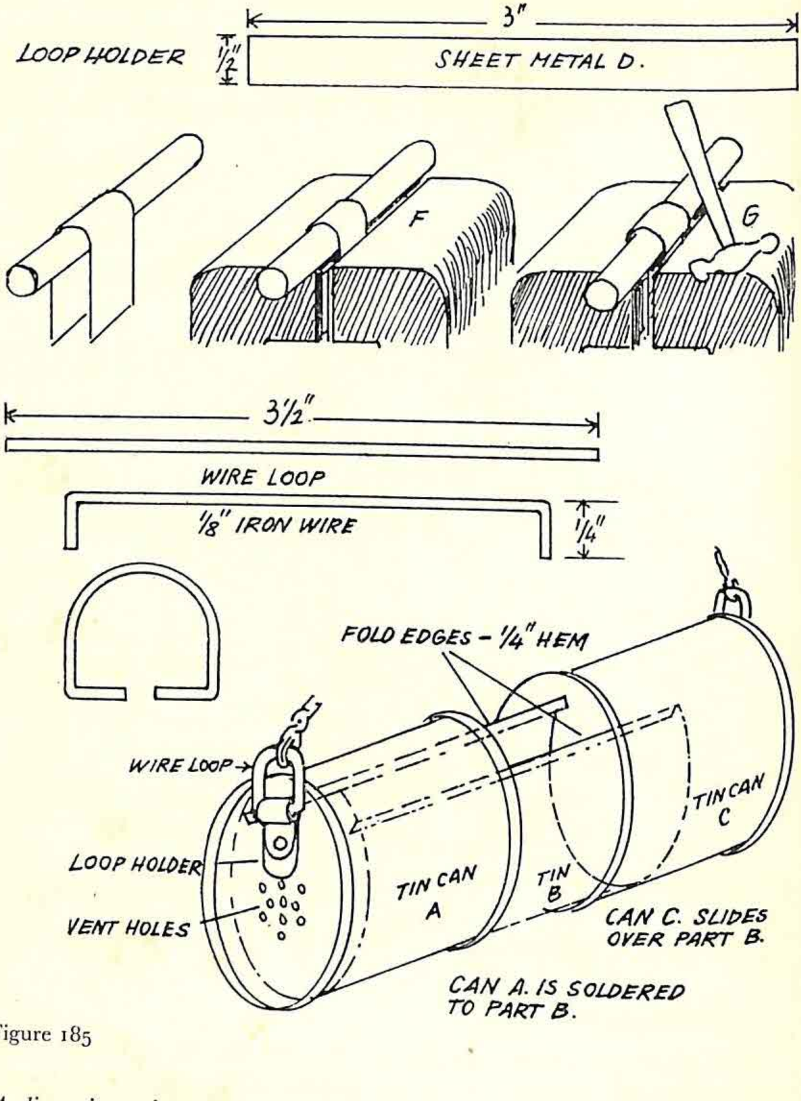


Figure 185

A dissecting microscope

This home-made dissecting microscope is simply a magnifying glass mounted above a glass dissecting stage. The microscope will, of course, only be as good as the lens used.
Use soft wood. All the joints should be simple butt joints, the parts being best held together by screws. Cut the glass platform,

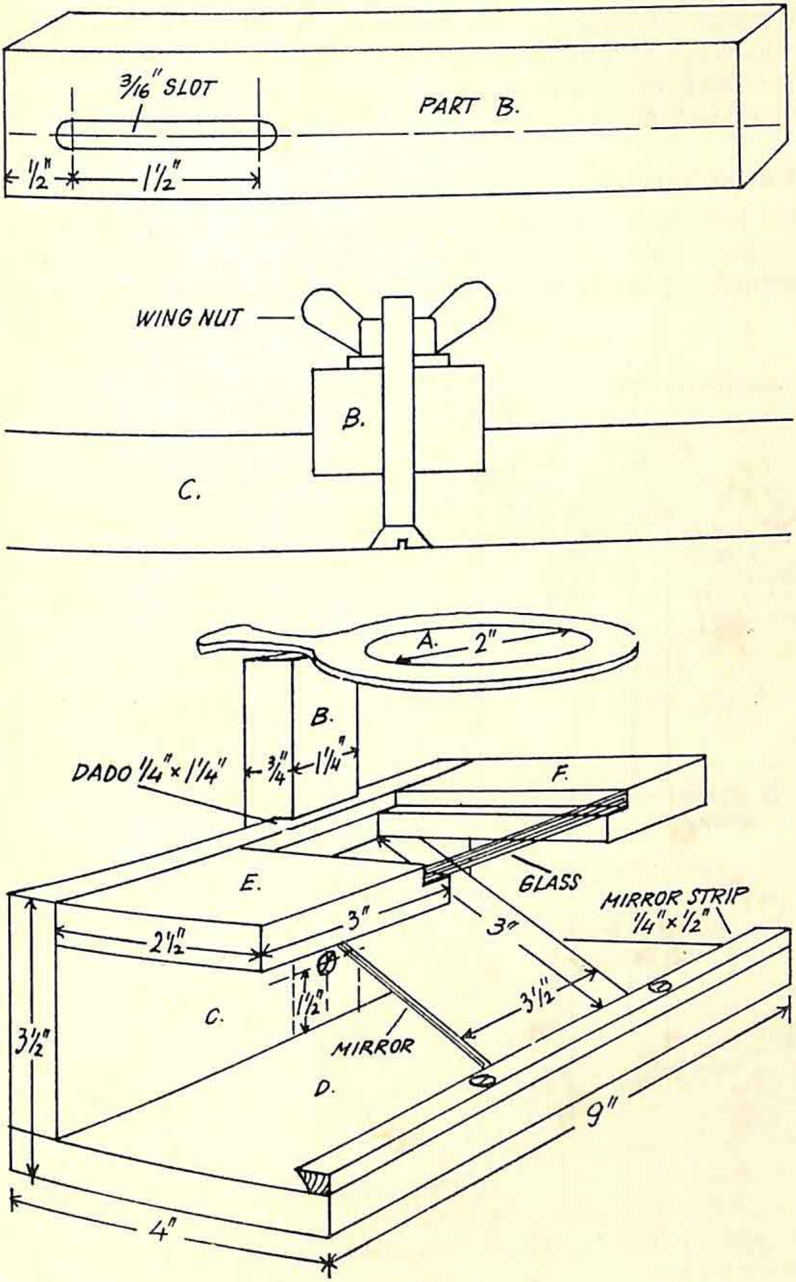

3/16" SLOT
PART B.
1/2"
1 1/2"
WING NUT
B.
C.
A.
2"
B.
DADO 1/4" x 1 1/4"
3/4"
1 1/4"
F.
E.
GLASS
MIRROR STRIP
1/4" x 1/2"
3"
3"
2 1/2"
1 1/2"
3 1/2"
3 1/2"
C.
MIRROR
D.
9"
4"

Figure 186

fit it after the other parts are assembled. In this way you can get a perfect fit. Old packing case wood can be used. If the wood is new, use $\frac{3}{4}$-inch or 1-inch stock.

Sandpaper all the parts and finish with shellac.

A simple microscope

The lens can be a water drop (glycerine mixed with water gives the best results) or a glass bead. A glass bead can be made by melting a piece of soft glass rod. The size of the 'hole' will

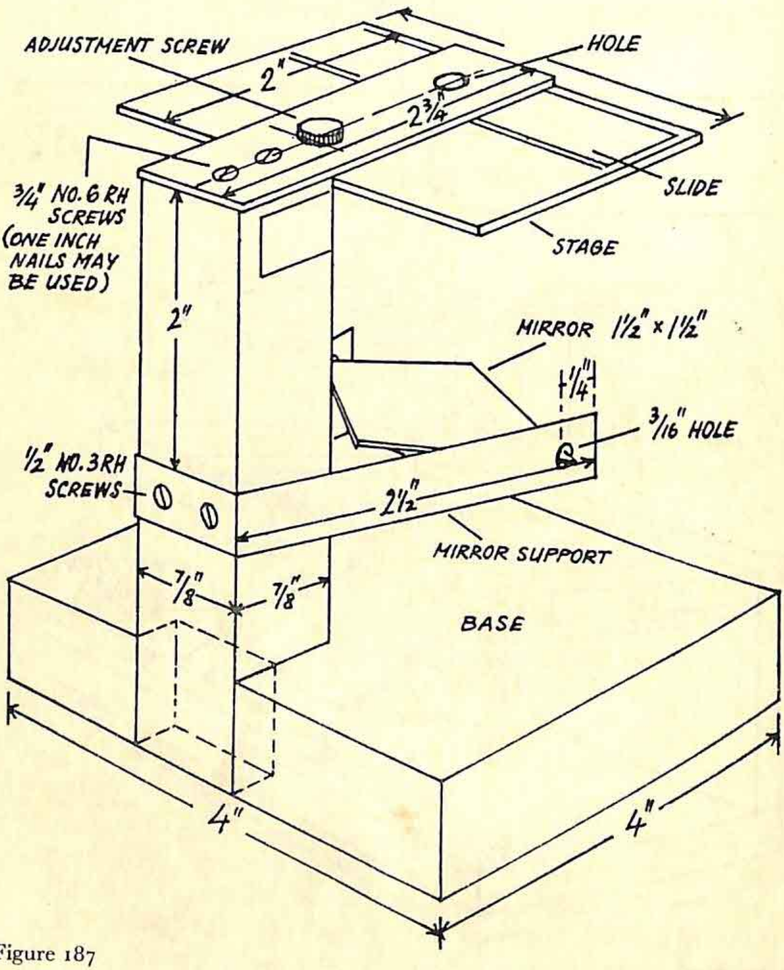


Figure 187

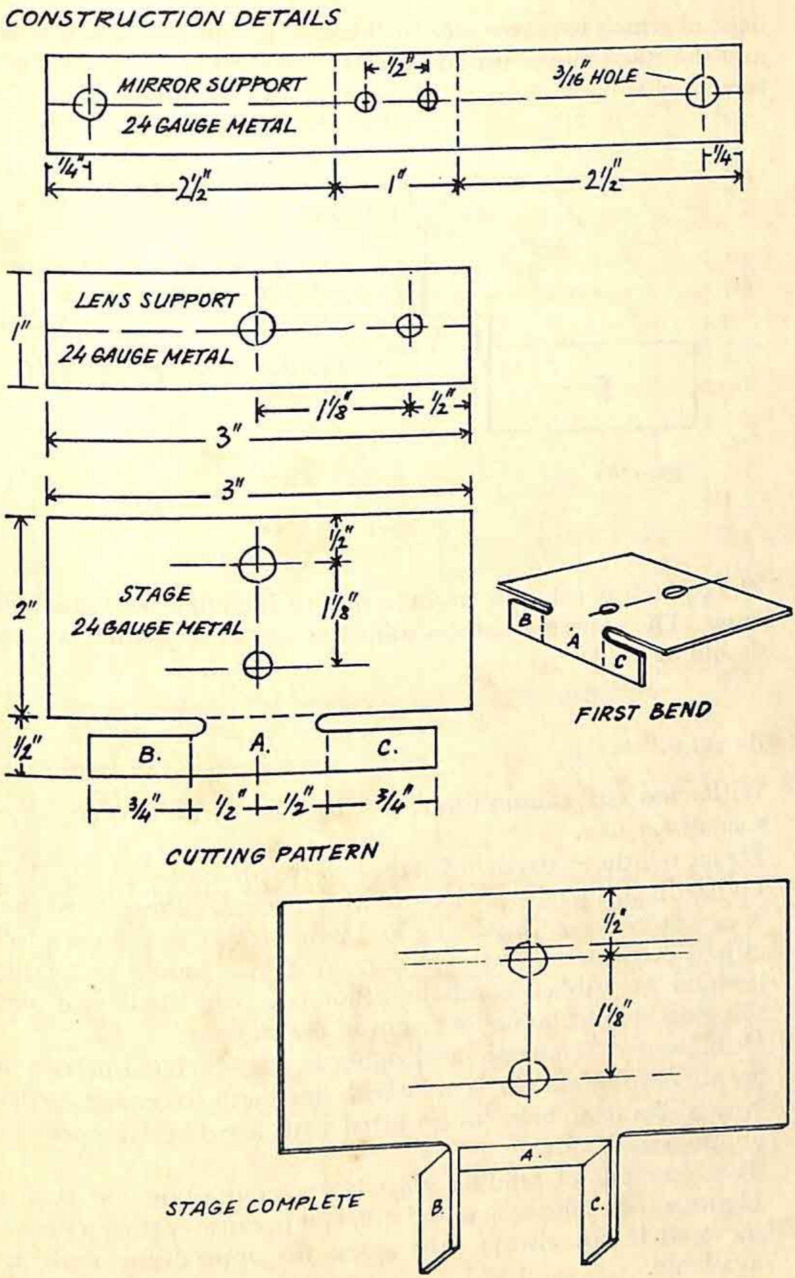

CONSTRUCTION DETAILS
MIRROR SUPPORT
24 GAUGE METAL
1/2"
3/16" HOLE
1/4"
2 1/2"
1"
2 1/2"
1/4
LENS SUPPORT
24 GAUGE METAL
1"
1 1/8"
1/2"
3"
3"
STAGE
24 GAUGE METAL
2"
1/2"
1 1/8"
B.
A.
C.
1/2"
3/4"
1/2"
1/2"
3/4"
CUTTING PATTERN
B
A
C
FIRST BEND
1/2"
1 1/8"
A.
B.
C.
STAGE COMPLETE

Figure 188

depend which lens you use. In this microscope the lens is fixed and the stage moves up and down by means of an adjustment screw made of brass.

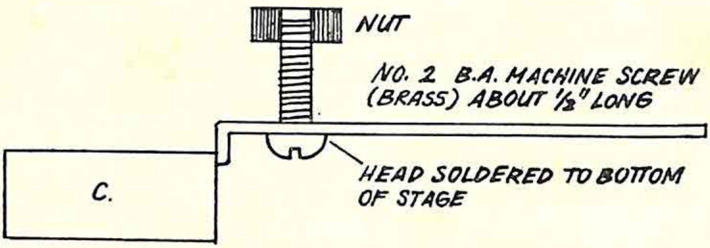


Figure 189

The $\frac{3}{16}$-inch slot should be cut to fit a $1\frac{3}{4}$-inch flat-head machine screw. The wing nut must also fit this screw. A $\frac{3}{16}$-inch washer should be used.

An ant palace

With a few adaptations this can be used for keeping worms or as a small beehive.

Figure 190 shows the detail of the construction.

Fit hardboard back only loosely with a couple of screws, so that it can be removed for filling and emptying. Use a loose piece of hardboard to cover the glass front (which should be held in position by rubber bands or cellotape): the hardboard over the glass should be easily removed for viewing.

Drill holes to fit a medicine dropper and a 1-inch diameter hole for air ventilation. Cover hole with fine mesh screening. Drill a $\frac{3}{4}$-inch diameter hole (to be fitted with a rubber stopper) for adding solid foods.

Two methods of holding glass fronts in position are shown. Figure 2 shows the easiest and quickest because cutting a groove in wood is not always easy unless the appropriate tools are available.

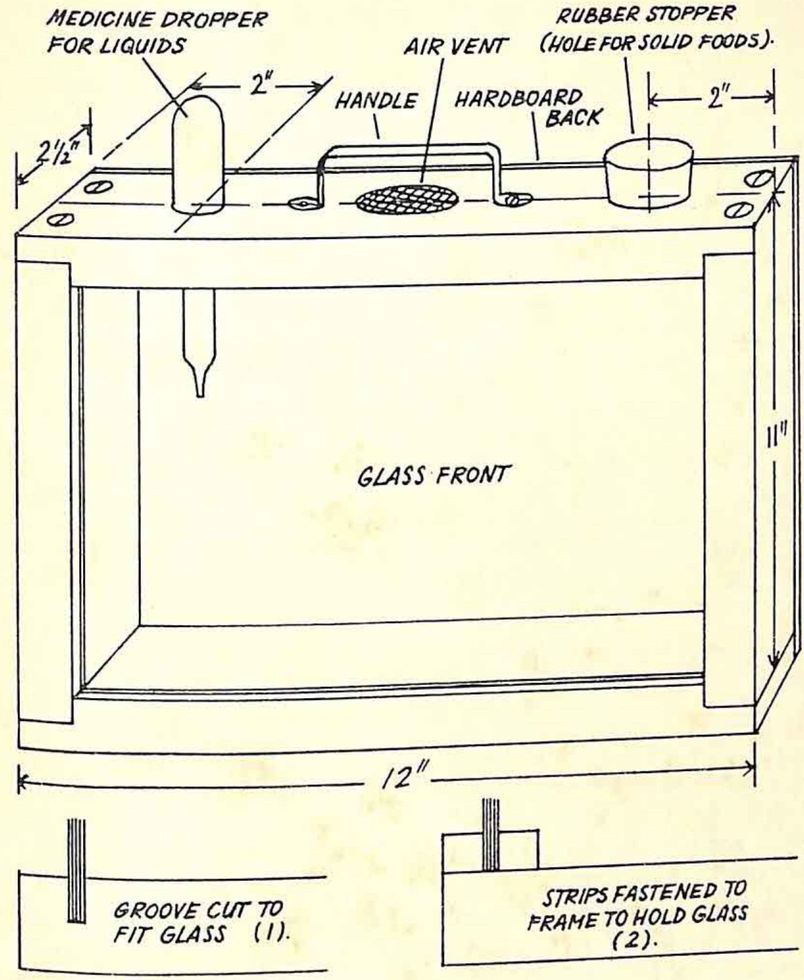

MEDICINE DROPPER
FOR LIQUIDS
AIR VENT
RUBBER STOPPER
(HOLE FOR SOLID FOODS).
2"
HANDLE
HARDBOARD
BACK
2"
2½"
GLASS FRONT
11"
12"
GROOVE CUT TO
FIT GLASS (1).
STRIPS FASTENED TO
FRAME TO HOLD GLASS
(2).

Figure 190

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